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PAPERS AND PROCEEDINGS

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A Revision of the Tasmanian Hydroida

By

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(Read 1st November, 1949)

With 92 Text Figures

The present paper gives an account of sixty-four species of Calyptoblastic Hydroids occurring in Tasmanian waters. This number includes sixteen forms not previously recorded from this region. Of these one is a new species, namely, *Halecium fragile*.

The specimens examined are from the east and south-east coasts, from the Derwent Estuary, and from the D'Entrecasteaux Channel. They were obtained partly by dredging and partly by shore-collecting.

Some of the Hydroids previously recorded from Tasmania were from deep water. Specimens of these have not been seen, and the descriptions given are based on those of previous authors. However, in other cases, existing descriptions have been carefully checked against new specimens, and, where necessary, measurements have been incorporated in the revised accounts.

PREVIOUS WORK

Investigations on the Calyptoblastic Hydroids from Tasmania are incomplete and few in number. With but one or two exceptions present knowledge is based on material obtained as part of larger collections of marine fauna, instead of on a specialized collection of Hydroida.

The first record of Hydroida from these regions concerns material obtained during the voyage of H.M.S. *Rattlesnake*, and described by Busk (1852).

In 1874 H.M.S. *Challenger* made some dredgings in Bass Strait, and the Hydroids obtained were described by Allman (1883, 1888).

D'Arcy Thompson (1879) wrote a paper on Hydroids from Australia and New Zealand. Included in this were descriptions of some specimens from Bass Strait and George Town.

Hydroids dredged off the Tasmanian coast by the F.I.S. *Endeavour* from 1909-1914, have been described by W. M. Bale (1914b, 1914c; 1915). In addition, E. A. Briggs (1914, 1915) has written two papers dealing with Hydroida from Tasmania.

The Hydroids collected by the Australasian Antarctic Expedition 1911-1914 were described by Briggs (1939). These included a few species dredged off Maria Island.

There are no records of any specimens having been found, or collections having been made, on the west and south-west coasts of Tasmania.

Key to Families and Genera

1.	No true hydrothecae or gonothecae	Gymnoblastea
2.	Hydrothecae and gonothecae present	Calyptoblastea 3
3.	Sarcothecae absent (except in *Phylactotheca and Perisiphonia*)	4
	Sarcothecae always present; hydrothecae sessile, on one side only of the stem or pinna	Plumulariidae 16
4.	Hydrothecae with a definite diaphragm	5
	Hydrothecae without a definite diaphragm, tubular with a smooth margin	Lafoëidae 10
5.	Hydrothecae tubular, wider than deep, biserial	Haleciidae 7
	Hydrothecae campanulate, generally deeper than wide, never adnate, operculum absent	Campanulariidae 8
	Hydrothecae ovato-conic, never adnate, operculum present	Campanulinidae 12
	Hydrothecae sessile, adnate or immersed	6
6.	Hydrotheca margin smooth	Syntheciidae 13
	Hydrotheca margin toothed	Sertularidae 14
7.	Sarcothecae present on hydrocaulus	*Phylactotheca*
	Sarcothecae never present	*Halecium*
8.	Gonothecae on hydrocaulus, free medusae	*Obelia*
	Gonothecae on hydrocaulus, fixed medusoid gonophores	*Gonothyraea*
	Hydrothecae terminal on short peduncles	9
9.	Medusae without manubrium	*Silicularia*
	Medusae without tentacles or digestive cavity	*Orthopyxis*
10.	Hydrocaulus monosiphonic	*Hebella*
	Hydrocaulus polysiphonic	11
11.	Peripheral tubes without sarcothecae	*Cryptolaria*
	Peripheral tubes bearing tubular sarcothecae	*Perisiphonia*
12.	Hydrocaulus internodes each bearing a pedunculate hydrotheca	*Thyroscyphus*
13.	Hydrocaulus internodes with paired, opposite hydrothecae; gonothecae arise from within certain hydrothecae	*Synthecium*
14.	Hydrothecae biserial, not in pairs, opposite to alternate	*Thuiaria*
	Hydrothecae always paired, opposite to alternate, internal operculum	15
	Hydrothecae alternate, one on an internode	*Sertularella*
	Hydrothecae spirally arranged in several longitudinal series	*Selaginopsis*
15.	Gonothecae differ in the sexes	*Diphasia*
	Gonothecae similar in the sexes	*Sertularia*
16.	Lateral sarcothecae moveable, wine glass shaped, bases narrow	17
	Lateral sarcothecae, when present, always fixed	18
17.	Branchlets pinnate	*Plumularia*
	Branchlets verticillate	*Nemertesia*
18.	Lateral sarcothecae present	19
	Lateral sarcothecae absent	20
19.	Gonothecae borne on the stem	*Halicornaria*
	Gonothecae borne in corbulae, or on modified pinnae	*Aglaophenia*
20.	Hydrothecae with a large anterior rostrum	*Halicornopsis*
	Hydrothecae without a rostrum	*Kirchenpaueria*

Sub-Order CALYPTOBLASTEA

Family *CAMPANULARIIDAE*

'Hydrothecae terminal, pedicellate, campanulate. Polypites with a large trumpet-shaped proboscis'. Hincks.

Genus **Obelia** Péron and Lesueur, 1809

'Stem branching, plant-like, rooted by a creeping stolon; hydrothecae campanulate, without operculum; gonothecae borne on the stem and branches; reproduction by free medusiform zooids.

Gonozooid: Umbrella (at the time of liberation), depressed and disk-like; manubrium short and quadrate; radiating canals 4; marginal tentacles numerous (increasing in number with age), prolonged at the base and projecting inwards; lithocysts 8 2 in each interradial space, borne on the inner side of 8 of the tentacles near the base'. Hincks.

Obelia geniculata (Linnaeus, 1758)

(Figs 1-4)

Sertularia geniculata Linnaeus, 1758.
Loamedea geniculata Lamouroux, 1816.
Campanularia geniculata Fleming.
Monopyxis geniculata Ehrenburg, 1834.
Eucope diaphana Agassiz, 1862.
Obelia geniculata Allman, 1864.
Eucope alternata A. Agassiz, 1865.

Trophosome: Hydrocaulus simple, monosiphonic, up to 2 cm. in height; stem markedly flexuous, or zig-zag, jointed at each flexure; immediately below each joint the perisarc is expanded to form a support for the annulated (4-6 rings) pedicel of the hydrotheca; one to three rings present on each stem internode distal to the joint. Hydrothecae obconical, rather short, with an entire margin; the supporting pedicel is almost erect, and tapers slightly from the base.

Gonosome: Gonothecae elongated and urn-shaped; aperture terminal in position and surrounded by a prominent collar of characteristic construction. The gonotheca arises in a position axillary to the pedicel of a hydrotheca and is supported by a short annulated stalk.

Dimensions:

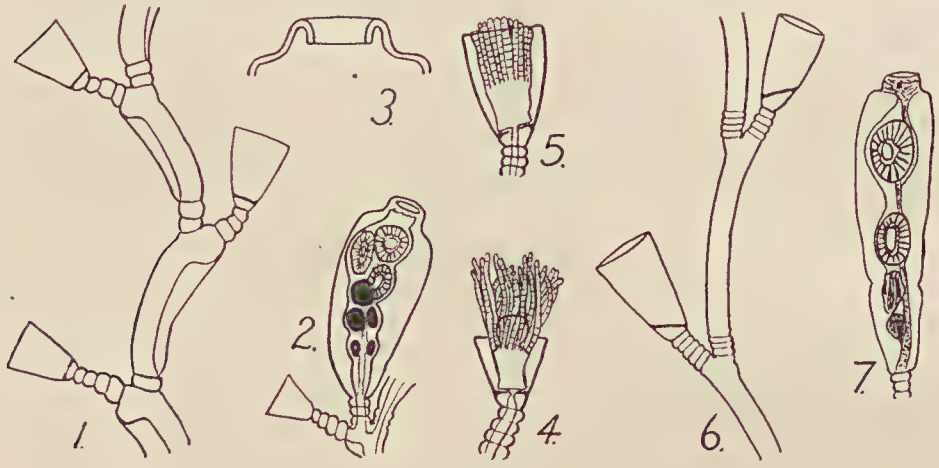
Hydrocaulus internode, length	0·72-0·75 mm.
Hydrocaulus internode, diameter (at joint)	0·13-0·16 mm.
Hydrotheca, depth	0·25-0·28 mm.
Hydrotheca, diameter (at aperture)	0·30-0·32 mm.
Gonotheca, length	0·75-0·80 mm.
Gonotheca, diameter	0·28-0·33 mm.

Locality: Garden Island Creek (December, 1948); Bellerive, Derwent Estuary (June, 1949).

Distribution: Recorded from Australia; New Zealand; Labrador; Massachusetts; European Seas.

The specimens from Garden Island Creek, which form the basis of this description, were found growing on the laminae of *Macrocystis* near the surface of the water. The hydrorhiza of the colonies formed a very extensive network covering the entire lamina.

The specimen differs from that described by Bale (1884, p. 59) in the possession of annuli on the hydrocaulus internodes, and also in the shape of the internodes, which are not as stout. In the possession of annuli the specimen agrees with the form described by Mulder & Trebilcock (1914, p. 44).



FIGS 1-7.

Obelia geniculata (Linnaeus). Fig. 1: Portion of colony. Fig. 2: Gonotheca showing medusae. Fig. 3: Longitudinal section through top of mature gonotheca. Fig. 4: Hydrotheca with partially expanded polyp. *Obelia australis* von Lendenfeld. Fig. 5: Hydrotheca with retracted polyp. Fig. 6: Portion of colony. Fig. 7: Gonotheca with two nearly mature medusae.

Obelia australis von Lendenfeld, 1884

(Figs 5-7)

Obelia australis von Lendenfeld, 1884.

Trophosome: Hydrocaulus monosiphonic, sparingly branched, attaining a height of about 3-4 cm.; stem flexuous, annulated (3-5 rings) distal to the origin of hydrothecae pedicels, also (8-10 rings) at the base of each branch, and the stem; pedicels annulated, those at the distal end of colony with 4-10 rings, those proximally placed with 10-20 rings, these later often having the central part smooth. Hydrothecae alternate, campanulate, not constricted at the level of the floor, which is very oblique and placed a little above the base; margin of aperture is entire and may be sinuous.

Gonosome: The gonothecae are urn-shaped and elongated, arising axillary to a branch hydrotheca, or both; the aperture is terminal with a collar surrounding.

Dimensions:

Hydrocaulus internode, length	up to 0·80 mm.
Hydrocaulus internode, diameter	0·10-0·11 mm.
Hydrotheca, length	up to 0·50 mm.
Hydrotheca, diameter at aperture	0·33-0·40 mm.
Gonotheca, length	up to 1·25 mm.
Gonotheca, diameter	0·43-0·44 mm.

Locality: Hobart (March, June, 1949); Maria Island, 65 fathoms (Briggs, December, 1912).

Distribution: Recorded from New South Wales; New Zealand; Gulf of Manaar, Ceylon.

The specimens were found growing on the piles of a jetty below low-tide level. The gonotheca resembles that of *Obelia geniculata*, but in some cases there is a transverse constriction, about half-way between base and apex. The specimen from Maria Island (Briggs, 1939, p. 14) was found growing epizoically on *Aglaophenia tasmanica* Bale.

Genus **Gonothyraea** Allman, 1864

'Stem erect and branched, rooted by a thread-like stolon; hydrothecae campanulate and hyaline; polypites with a prominent contractile proboscis; reproduction by fixed medusiform sporosacs which are furnished with a circlet of filiform tentacles, and, when mature, become extra-capsular, and are borne on the summit of the gonotheca'. Hincks.

Gonothyraea hyalina Hincks, 1868

(Figs 8-11)

Gonothyraea hyalina Hincks, 1868.'

?Calycella parkeri Hilgendorf, 1897.

?Gonothyraea parkeri Bale, 1924.

Trophosome: Hydrocaulus monosiphonic, branched, attaining a height of about 3 cm.; stem flexuous, jointed, giving rise to a branch, hydrotheca, or both, at each joint; stem annulated at the base, and distal to each joint, as are the branches. Hydrothecae alternate, elongate, campanulate, hyaline; aperture circular, margin castellated, the denticles being indented at the top; hydrothecae are borne on annulated (up to 20 rings), slightly tapering pedicels.

Gonosome: Sexes are separate, the colony being either male or female. Gonothecae are large, axillary to a branch of hydrothecae, urn-shaped with a flattened top, supported by a ringed pedicel; gonophores become extra-capsular at maturity, but are not liberated.

Dimensions:

Hydrocaulus internode, length	up to 0·75 mm.
Hydrocaulus internode, diameter	0·08-0·10 mm.
Hydrotheca, length	0·43-0·47 mm.
Hydrotheca, diameter	0·20-0·25 mm.
Gonotheca, length	up to 0·80 mm.
Gonotheca, maximum diameter	0·40 mm.

Locality: Hobart, Derwent Estuary (March, 1947, 1949).

Distribution: England; New Zealand (?).

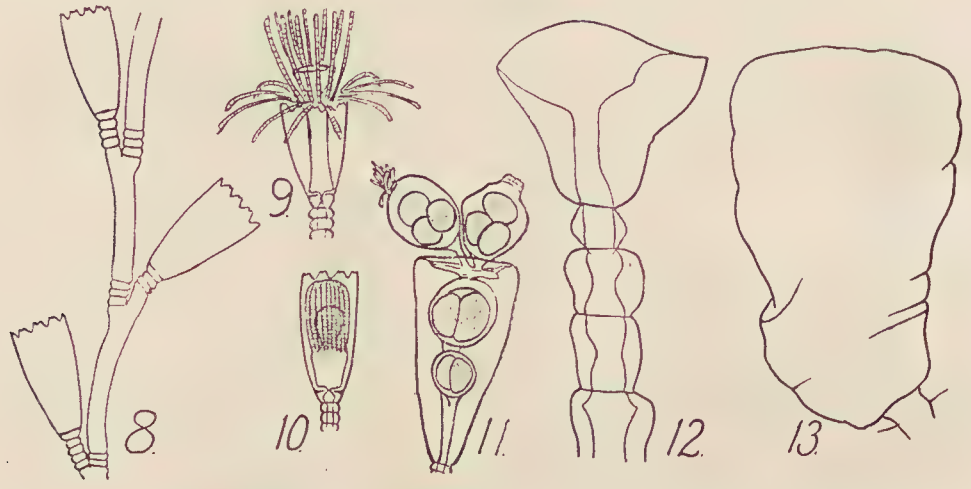
The hydranth when expanded is long and thin, with a large extensible trumpet-shaped proboscis; the single ring of twenty-four extremely long tentacles has the appearance of two rings (fig. 9). The appearance of the polyp in the retracted state is very characteristic, the tentacles being drawn just within the margin of the hydrotheca (fig. 10).

The trophosome of this genus closely resembles that of some species of *Obelia*, except in the structure of the reproductive organs. The female gonophores on becoming extra-capsular at maturity contain three to five large ova which are not liberated. Fertilisation and development to the motile planular stage

takes place within the sporosac. The male gonophores become extra-capsular in a similar way, but here the spermatozoa are discharged shortly after emergence.

The present specimen is the first record of *Gonothyraea hyalina* from the Southern Hemisphere. However, Bale (1924, p. 231) discusses a *Gonothyraea parkeri*, originally described from Dunedin by Hilgendorf under the name of *Calycella parkeri*, which he considers is probably identical with *Gonothyraea hyalina* Hincks.

This species lives in a position so as to become exposed at very low tides, a feature also noted by Hilgendorf in the case of *Gonothyraea parkeri*.



FIGS 8-13.

Gonothyraea hyaline Hincks. Fig. 8: Portion of colony. Fig. 9: Hydrotheca with expanded polyp. Fig. 10: Hydrotheca with contracted polyp. Fig. 11: Female gonotheca with two emergent medusoid gonophores containing mature ova. *Silicularia campanularia* (von Lendenfeld). Fig. 12: Distal portion of peduncle with terminal hydrotheca. Fig. 13: Gonotheca.

Genus **Silicularia** Meyen, 1834

'Trophosome similar to that of Campanularia; gonophores consisting of free medusoids which are destitute of a manubrium'. Bale.

Silicularia campanularia (von Lendenfeld, 1884)

(Figs 12, 13)

Eucopella campanularia, in part, von Lendenfeld, 1884.
Eucopella campanularia Bale, 1888.
?Eucopella reticulata Hartlaub, 1905.
Silicularia campanularia Bale, 1914a.

Trophosome: Hydrorhiza broad and flat; hydrothecae terminal on short unbranched peduncles which arise at right angles to the hydrorhiza. The length of the peduncles is very variable as is the number of joints (1-3) which may occur immediately below the spherule; spherule single lying between the hydrotheca and the peduncle. Perisarc of spherule and peduncle may be thickened, not necessarily corresponding to the external outline. Hydrotheca has no cavity corresponding to the external outline, a considerable portion being filled with

solid perisarc; the cavity is shallow and eccentrically placed towards the lower side of the hydrotheca; from the base of this cavity a tube leads to the spherule.

Gonosome: Gonothecae ovate, broad and flattened, attached to the hydrorhiza by a short stalk; at maturity a single medusoid is liberated.

Dimensions:

Peduncle, length	up to 2.5 mm.
Peduncle, diameter	0·13-0·16 mm.
Hydrotheca, length	0·48-0·55 mm.
Hydrotheca, diameter at aperture	0·47-0·58 mm.
Spherule, diameter	0·10-0·11 mm.
Spherule, length	0·13 mm.
Gonotheca, length	up to 1·50 mm.
Gonotheca, breadth	up to 1·00 mm.

Locality: South Arm, Derwent Estuary (April, 1947, 1949); Oyster Bay (May, 1949).

Distribution: Recorded from Victoria; New South Wales.

In life the polyp leans towards one side of the hydrotheca, into which it is not fully retractile; successive joints of the peduncle differ in length, but corresponding joints on different peduncles, are, as a general rule, equal and constant.

The specimens were found growing on various algae, the growth of the colonies often being very extensive. The specimen from South Arm (April, 1949) was found near low-tide mark, and that from Oyster Bay on storm drifted *Macrocystis*.

Genus **Orthopyxis** L. Agassiz, 1862

'Trophosome consisting of smooth or undulated peduncles of varying lengths, springing from a creeping hydrorhiza, and supporting each a single hydrotheca; hydrothecae campanulate with the lower part compressed but usually circular above the perisarc varying much in thickness but always greatly thickened inwards near the base so as to form a floor on which the hydranth is supported; hydranth radially symmetrical, with about 24-32 tentacles and a large trumpet-shaped hypostome. Gonothecae variable in form within the limits of a species; gonozooid a modified medusa, having neither tentacles nor digestive cavity but provided with four branched radial canals, and sometimes with marginal sense organs'. Bale.

Orthopyxis caliculata (Hincks, 1853)

(Figs 14-16)

Campanularia caliculata Hincks, 1853.
Campanularia breviscyphia Sars, 1857.
Laomedea caliculata Allman, 1864.
Clytia (Orthopyxis) poterium Agassiz, 1862.
Orthopyxis poterium A. Agassiz, 1865.
Campanularia poterium Nutting, 1901.
Clytia caliculata Nutting, 1901.
Eucopella caliculata Fraser, 1911.
Campanularia integra Levinsen, 1892.

Trophosome: Hydrorhiza a flattened, ribbon-like stolon bearing short upright shoots, or peduncles, of varying lengths; peduncles distinctly undulated and may be jointed distally; terminally on each peduncle is borne a single hydrotheca and immediately below, between the hydrotheca and the end of the peduncle,

is a single spherule. Hydrothecae campanulate, with the lower part exhibiting bilateral development in being distinctly compressed; the perisarc of hydrotheca walls is thickened towards the base to form a support for the hydranth.

Gonosome: Gonothecae elongate, ovate or oblong, smooth, somewhat compressed; at maturity they are rounded at the top. However, as with trophosome, wide variations are possible.

Dimensions:

Peduncle, length	up to 1·25 mm.
Peduncle, diameter	0·08-0·11 mm.
Spherule, length	0·41-0·44 mm.
Spherule, diameter	0·48-0·51 mm.
Hydrotheca, length	0·14-0·33 mm.
Hydrotheca, depth	0·11-0·26 mm.
Gonotheca, length	1·00 mm.
Gonotheca, diameter	0·50 mm.

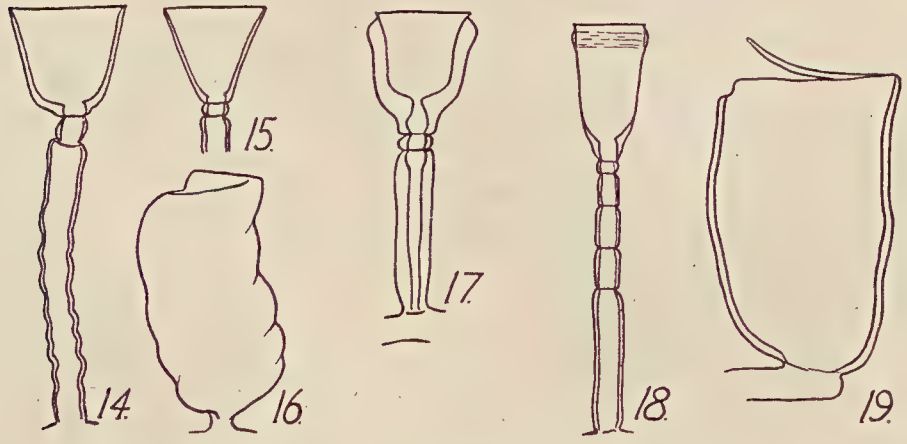
Locality: Eaglehawk Neck (February, 1948); Bicheno; Oyster Bay; Rheban (May, 1949).

Distribution: Cosmopolitan.

The specimens in this collection agree with the description by Bale (1914a, p. 74). As can be seen from the measurements above, there is a very wide variation in the trophosome measurements even in the one colony.

The bilateral symmetry of the hydrotheca is illustrated in figs 14, 15; in 'front' view the hydrotheca remains wide as far as the platform on which the hydranth is supported, with the walls more or less thickened, whilst in 'side' view the appearance is markedly conical with thin walls.

The specimen from Eaglehawk Neck was growing epizoically on *Plumularia setacea* (Ellis) just below low-tide level. The other specimens were taken from storm-drifted sea-weed.



FIGS 14-19.

Orthopyxis caliculata (Hincks). Fig. 14: Peduncle and terminal hydrotheca in broad aspect. Fig. 15: Hydrotheca in narrow aspect. Fig. 16: Gonotheca. *Orthopyxis angulata* Bale. Fig. 17: Peduncle and hydrotheca of the thickened type. Fig. 18: Peduncle and hydrotheca of the unthickened type. Fig. 19: Gonotheca.

Orthopyxis angulata Bale, 1914

(Figs 17-19)

Orthopyxis angulata Bale, 1914a.

Trophosome: Hydrorhiza a broad thickened ribbon, bearing stout upright shoots or peduncles of varying lengths; peduncles thickened, smooth, narrowed at point of origin, sometimes with one or more joints or constrictions towards the distal end; a single spherule between the distal end of peduncle and the terminal hydrotheca. Hydrothecae single and terminal on a shoot; bilaterally developed, in broad view being wide at base with the floor markedly flattened due to a thickening of perisarc; walls thickened, either for whole length, or in the form of a convex band running round the hydrotheca just below the margin; in narrow view hydrotheca appears almost conical, with thin walls, except for the continuation of sub-marginal band; aperture elliptical, margin entire, slightly everted.

Gonosome: Gonothecae broad, flattened; in broad view they appear ovate, truncate, with undulated edges, a little contracted towards the top, then widening to form two angular projections; top flat or slightly concave between the projections.

Dimensions:

Peduncle, length	up to 3·17 mm.
Peduncle, diameter	0·08-0·17 mm.
Spherule, length	0·05-0·07 mm.
Spherule, diameter	0·05-0·10 mm.
Hydrotheca, length	up to 0·54 mm.
Hydrotheca, diameter at aperture	up to 0·25 mm.
Gonotheca, length	1·08 mm.
Gonotheca, breadth	0·83 mm.

Locality: D'Entrecasteaux Channel, 10-12 fathoms (July, 1949); Blackman's Bay, Derwent Estuary, 3-4 fathoms (July, 1949).

Distribution: Recorded from Pt. Phillip (Wilson).

The specimens from the two localities show a marked contrast in the shape of the hydrotheca. However, Bale (1914a, p. 82) states that this wide variation in size and shape is not inconsistent with the allocation of the two forms to the one species.

The specimen from D'Entrecasteaux Channel has the peduncle jointed for some distance below the spherule; the internodes are unequal in length, the proximal the longest, with the others in a decreasing series. Hydrothecae have thin walls except for a convex band round the theca just below the margin, which is entire, slightly everted, with a rim that is smooth or very slightly undulated. Specimen was growing on *Macrocystis* lamina.

The specimen from Blackman's Bay differs in several points. Peduncle is not jointed. Hydrothecae are thickened bilaterally, giving the effect of strong compression; aperture is circular or nearly so; margin entire, smooth or slightly undulated, everted. This specimen was also found growing on *Macrocystis* lamina, with the hydrorhiza of the colony very wide-spread.

Family CAMPANULINIDAE

'Hydrothecae ovato-conic, pedicellate; polypites cylindrical, with a small conical proboscis'. — Hincks.

Genus **Thyroscyphus** Allman, 1877

'Hydrocaulus composed of consecutive internodes each supporting a pedunculate hydrotheca. Hydrothecae with the cavity divided from that of peduncle by a perforated diaphragm, and having the orifice surmounted by a roof which is composed of four triangular membranous valves'. — Allman.

Thyroscyphus simplex (Lamouroux, 1816)

(Fig. 22)

Laomedea simplex Lamouroux, 1816.
Campanularia tridentata Bale, 1894.
Sertularella tridentata Hartlaub, 1900.
Thyroscyphus tridentatus Hartlaub, 1901.
Thyroscyphus simplex Billard, 1909.
Parascyphus simplex Ritchie, 1911.

Trophosome: Hydrocaulus simple, monosiphonic, attaining a height of about 2-3 cm.; stem divided into internodes each bearing a short process from which springs a hydrotheca. Hydrothecae alternate, tubular above, curving inwards towards the base on the upper side only; the lower, outer wall is straight or concave, the upper strongly convex; the aperture has three pointed teeth (emarginations), and an operculum of three pieces.

Gonosome: Gonothecae up to four in number, borne proximally on hydrocaulus; ovate, elongate, smooth, with a rounded top and a small circular aperture; margin thickened but not elevated.

Dimensions:

Hydrocaulus internode, length	0·66-0·75 mm.
Hydrocaulus internode, diameter	0·15-0·20 mm.
Hydrotheca, length	0·66-0·70 mm.
Hydrotheca, diameter at aperture	0·20-0·22 mm.
Hydrotheca, diameter at base	0·08-0·10 mm.
Gonotheca, length	up to 1·40 mm.
Gonotheca, diameter	up to 0·60 mm.

Locality: D'Entrecasteaux Channel; Seven miles east of Cape Pillar, 100 fathoms (Briggs).

Distribution: Recorded from Australia (Lamouroux); Port Phillip, Victoria (Bale); French Pass, New Zealand (Hartlaub); Gough Island, South Atlantic (Ritchie); Clyde Sea Area, Barrier Plateau, between Sanda Island and Ailsa Craig, 24 fathoms (Ritchie); Forty miles west of Kingston, S.A., 30 fathoms (Bale); Fifty miles south of C. Wiles, S.A., 75 fathoms (Bale).

The discrepancy in the number of opercular teeth given in Allman's generic description, compared with the number in Bale's description of *Campanularia tridentata* is considered by the latter to be of little importance.

The specimen was growing on the shell of the scallop *Notovola fumatus*.

Gonothecae are lacking in this specimen, the measurements being those given by Briggs (1914, p. 288).

Family LAFOËIDAE

'Hydrothecae tubular; polypites cylindrical, with a conical proboscis'. Hincks.

Genus **Lafoea** Lamouroux, 1821

'Stem a simple, creeping, tubular fibre, or erect and composed of many tubes aggregated together, rooted by a filiform stolon; hydrothecae tubular, sessile or with a short pedicel, without an operculum, more or less regularly disposed on the stem and branches; polypites cylindrical, with a conical proboscis'. — Hincks.

Lafoëa fruticosa (Sars, 1850)

Campanularia fruticosa Sars, 1850.
Campanularia gracillima Alder, 1857.
Calicella fruticosa Hincks, 1861b.
Lafoëa gracillima G. O. Sars, 1874.
Lafoëa fruticosa Sars, 1862.

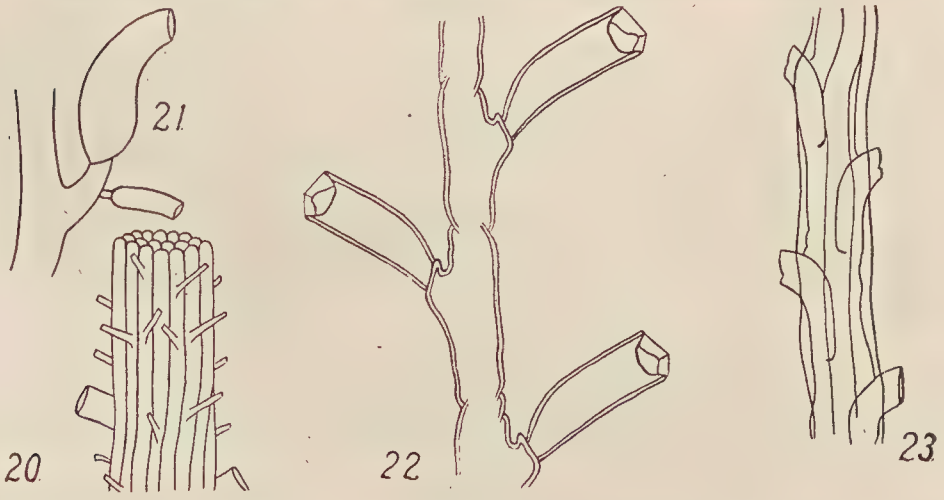
Trophosome: Hydrocaulus erect, polysiphonic, irregularly and often subunilaterally branched, attaining a height of about 7-8 cms. Hydrothecae long, slender, slightly curved with thin walls, borne on short pedicels which are either annulated (3-4 rings) or loosely twisted; aperture entire, margin smooth.

Locality: Bass Strait (Busk).

Distribution: Recorded from Great Britain; Bergen; North Cape; Iceland.

The specimen from Bass Strait, in Busk's collection, has been examined by Hincks who states he has 'little doubt that it is identical with the present species'.

Dimensions are not given. There is no specimen in this collection.



FIGS 20-23.

Perisiphonia exserta (Busk). Fig. 20: Distal end of pinna (after Allman). Fig. 21: Outline of hydrotheca showing a sarcotheca springing from its peduncle (after Allman). *Thyroscyphus simplex* (Lamouroux). Fig. 22: Portion of colony with hydrotheca. *Cryptolaria arboriformis* Ritchie. Fig. 23: Portion of fascicled branch with hydrothecae (after Ritchie).

Genus **Perisiphonia** Allman, 1888

'Hydrocaulus composed of two constituents, an axial and a peripheral; the axial formed by a continuous tube which carries at intervals along its length numerous tubes which completely surround the axial in its entire length, are

destitute of hydrothecae, but allow the hydrothecae of the axial tube to protrude through interstices between them into the surrounding water; the superficial tubes of the peripheral fascicle set with tubular sarcothecae'. Allman.

Perisiphonia exserta (Busk, 1858)

(Figs 20, 21)

Cryptolaria exserta Busk, 1858.
Perisiphonia filicula Allman, 1888.
Perisiphonia exserta Ritchie, 1911.

Trophosome: Hydrocaulus slender, polysiphonic, attaining a height of about 6 cm.; from the stem hydrocladia (pinnae), which may be slightly fascicled, arise in sub-opposite pairs lying in the same plane. Hydrothecae borne in two opposite series on axial tubes, regularly alternate, lying in one plane; hydrothecae cylindrical, adpressed to the axial tube for two-thirds of length, distal portion projecting through the fascicle of peripheral tubes; aperture round, margin smooth, slightly everted, little tendency to regeneration, not more than two reduplicated margins. Base of hydrotheca passes into an expanded portion of axial tube which represents a pedicel, this is marked by a strong oblique diaphragm. Sarcothecae occur on the stem and pinnae; more or less regularly placed on the external peripheral tubes; short, cylindrical, each placed on a forward projecting process which tapers towards distal end where the diameter is less than that of free portion of the sarcotheca.

Gonosome: Unknown.

Dimensions:

Peripheral tube, diameter	0·05-0·06 mm.
Hydrotheca, length adnate to axial tube	0·33-0·34 mm.
Hydrotheca, length free from axial tube	·012-0·15 mm.
Hydrotheca, diameter at mouth	0·12 mm.
Sarcotheca, length	0·05-0·06 mm.
Sarcotheca, diameter	0·035 mm.
Distance between adjacent hydrothecae on hydroclades	0·47-0·51 mm.

Locality: Seven miles east of C. Pillar, 100 fathoms (Briggs); Oyster Bay, 60 fathoms (Bale); Thirty-five miles south-east of Bruni Island, 150-230 fathoms (Bale).

Distribution: Recorded from Madeira, North Atlantic (Johnson); Station 75, near the Azores, Lat. 38° 38′ N., Long. 28° 28′ 30″ W., 450 fathoms (Allman); Station 163a, off Twofold Bay, N.S.W., 150 fathoms (Allman); Station 57, off Wata Mooli, N.S.W., 54-59 fathoms (Ritchie); Great Australian Bight, Long. 130° 40′ E., 160 fathoms (Bale).

The measurements quoted above are those given by Briggs (1914, p. 290), there being no specimen in this collection.

Genus **Cryptolaria** Busk, 1858

'Hydrocaulus consisting of two parts, an axial and a peripheral, the peripheral consisting of a fascicle of simple tubes, the axial of a single tube, simple or branched, whose proximal portion lies under cover of the peripheral, and whose distal portion is free. Hydrothecae borne both by the covered and free portions of the axial tube, tubiform, destitute of peduncles, with the cavity directly continuous with that of the axial tube, and with their walls never adnate to the axial tube, where this is covered

by the peripheral fascicle, but more or less adnate to the tube in the free portion of its course. Gonangia consisting of sac-like receptacles which spring at intervals from the axial tube and protrude externally through interstices between the peripheral fascicle'. Allman.

Cryptolaria arboriformis Ritchie, 1911

(Fig. 23)

Cryptolaria arboriformis Ritchie, 1911.

Trophosome: Hydrocaulus branched, polysiphonic, attaining a height of about 15 cm.; branches fascicled and very irregular; ultimate branchlets fascicled, lying in one plane and arising pinnately; the axial tube not jointed, but bearing alternate hydrothecae at regular intervals. Hydrothecae in one plane, close-set, small, elongate, adnate for most of length, narrow at base but widening upwards, concealed by peripheral fascicle except for a short free portion which curves outwards at an angle of about 50° to the axis; aperture round, slightly contracted, margin not reduplicated; no diaphragm at base of theca, but lower end of adcauline wall bends outwards towards abcauline wall to form a small ledge.

Gonosome: Unknown.

Dimensions:

Fascicle tube, diameter	0·07 mm.
Axial tube, diameter	up to 0·45 mm.
Hydrotheca, length of adnate portion	0·28-0·31 mm.
Hydrotheca, length of free portion	0·08-0·10 mm.
Hydrotheca, greatest diameter	0·10-0·12 mm.

Locality: Seven miles east of Cape Pillar, 100 fathoms (Briggs); Twenty-one miles N. 62° E. of Babel Island, Bass Strait (Bale).

Distribution: Recorded from Station 44, off Coogee, New South Wales, 49-50 fathoms (Ritchie).

The measurements recorded above are those given by Briggs (1914, p. 289), there being no specimen in this collection.

Genus **Hebella** Allman, 1888

'Hydrocaulus a creeping monosiphonic stolon. Hydrothecae cylindrical, with entire margin, destitute of operculum, and with the cavity distinctly differentiated from that of the peduncle'. — Allman.

Hebella calcarata (L. Agassiz, 1862) var. contorta Marktanner-Turneretscher, 1890

(Fig. 24)

Hebella contorta Marktanner-Turneretscher, 1890.

Hebella cylindrica, in part, Pictet, 1893.

Hebella scandens, in part, Bale, 1913.

Not *Lafoëa cylindrica* von Lendenfeld, 1884.

Hebella calcarata, in part, Billard, 1907b.

Trophosome: Hydrocaulus slender, monosiphonic, branching, bearing hydrothecae on very short pedicels. Hydrothecae straight, slightly curved or twisted; rounded near the level of the diaphragm which separates the cavity from that of the pedicel; basal portion below the diaphragm short; aperture simple, margin smooth, slightly everted.

Dimensions:

Hydrotheca, length (Marktanner-Turneretscher)	0·46 mm.
Hydrotheca, length (Bale)	0·37-0·40 mm.
Hydrotheca, diameter	0·15 mm.

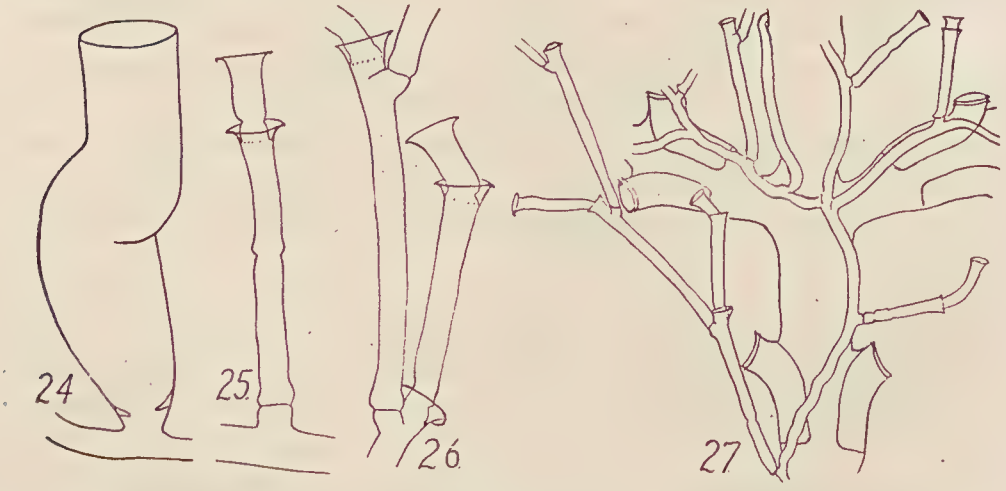
Locality: Ten miles north of Circular Head, on *Sertularia unguiculata* Busk (Bale).

Distribution: Recorded from New South Wales (Ritchie); Singapore (Marktanner-Turneretscher).

Bale (1915, p. 254) says; 'There is room for a difference of opinion as to whether *H. contorta*, which is distinguished from *H. calcarata* by the smaller size and somewhat twisted form of the hydrothecae, should be regarded as a distinct species'. He goes on to state that his specimens, compared with those of Marktanner-Turneretscher, had the hydrotheca rather less twisted, and in some cases not at all.

The dimensions above are the only ones given, there not being a specimen in this collection.

This species, in common with *Hebella calcarata*, is only found in association with another hydroid.



Figs 24-27.

Hebella calcarata var. *contorta* Marktanner-Turneretscher. Fig. 24: Hydrotheca arising from creeping hydrocaulus (after Marktanner-Turneretscher). *Halecium fragile* n.sp. Fig. 25: Shoot composed of a single internode with terminal hydrophores. Fig. 26: Portion of a shoot. Fig. 27: Portion of colony growing on *Synthecium patulum* (Busk).

Family HALECIIDAE

'Hydrothecae biserial, subsessile, jointed to a lateral process from the stem; polypites partially retractile'. Hincks.

Genus **Halecium** Oken, 1815

'Zoophyte plant-like, more or less branched, rooted by a creeping stolon; hydrothecae biserial, tubular or deeply campanulate, subsessile, jointed to a short lateral process from the stem; polypites partially retractile, large and fusiform; gonothecae scattered, dissimilar in the two sexes; reproduction by means of fixed sporosacs'. — Hincks.

Halecium fragile n. sp.

(Figs 25-27)

Trophosome: Hydrorhiza a creeping, filiform stolon, smooth or irregularly undulated. Hydrocaulus monosiphonic, sparingly branched or simple, consisting of shoots which attain a length of about 4-5 mm.; shoots flexuous, composed of long cylindrical internodes which are smooth or marked with irregularly placed transverse constrictions; internodes alternate, variable in length, each arising from a small lateral process immediately below the terminal hydrophore of the preceding one. Hydrophores tubular, shallow, expanded from diaphragm to margin which is smooth, and strongly everted; hydrophores may be regenerated up to four times each successive one arising at the level of the diaphragm of the former.

Gonosome: Gonothecae not present.

Dimensions:

Hydrorhiza, diameter	0·05-0·07 mm.
Hydrocaulus, internode, length	0·70-1·66 mm.
Hydrocaulus internode, diameter	0·05-0·08 mm.
Hydrophore, diameter at aperture	0·12-0·15 mm.
Hydrophore, diameter at diaphragm	0·07-0·08 mm.
Hydrophore, depth (margin to diaphragm)	0·036-0·042 mm.

Locality: D'Entrecasteaux Channel.

The specimen was growing epizoically upon a colony of *Synthecium patulum* (Busk), which was attached to the shell of the Commercial Scallop, *Notovola fumatus*.

The hydrorhiza of the specimen is a simple unjointed tube which, similar to the habit of *Hebella*, grows up the main stem of the host, giving off branches to the pinnae.

Shoots are very short, delicate, not exceeding 5 mm. in length, borne on small processes of the hydrorhiza; the form varies from single internodes with terminal hydrophores to shoots composed of a number of internodes, but usually not more than five or six.

The method of growth is cymose, typical of the Haleciidae. Each successive internode arises on a small lateral process beneath the terminal hydrophore of the preceding one. Shoots are normally unbranched, but in one case an internode bears no terminal hydrophore, but gives rise to two internodes (branches); and in two cases, two internodes (branches) arise beneath the terminal hydrophore.

The internodes may be marked by transverse constrictions which are not laid down in any regular or systematic plan.

The hydrophores each have a circlet of refractile puncta at the level of the diaphragm. The regenerated (secondary) hydrophores may be short, but in some cases the basal portion is nearly as long as one of the stem internodes.

The type specimen is in the Australian Museum.

Halecium flexile Allman, 1888

(Figs 25-27)

Halecium flexile Allman, 1888.
Halecium gracile Bale, 1888.
Halecium parvulum Bale, 1888.
Halecium balei Fraser, 1911.
No. 16, *Halecium* sp. Inaba, 1890.

Trophosome: Hydrocaulus branching, polysiphonic, attaining a height of about 2 cm.; branching irregular, with stem and branches flexuous, divided into long internodes by twisted oblique joints. Hydrophores alternate, borne at the distal end of the internode, tubular, with an everted margin, and often with secondary calycles arising within the old ones.

Gonosome: 'The male is pyriform, or club-shaped, laterally compressed, attached to the hydrocaulus by a short peduncle, and not terminal on a branch.

The female large, ovate, compressed, sporosac decidedly narrower than the capsule, with a space at the upper part not occupied by ova'. Bale, 1888.

Dimensions:

Hydrocaulus internode, length	0·57-0·66 mm.
Hydrocaulus internode, diameter	0·13-0·16 mm.
Hydrotheca, depth	0·06-0·08 mm.
Hydrotheca, diameter at aperture	0·15-0·16 mm.
Hydrotheca, diameter at base	0·08-0·10 mm.
Gonotheca, length	up to 0·60 mm.
Gonotheca, breadth	up to 0·50 mm.

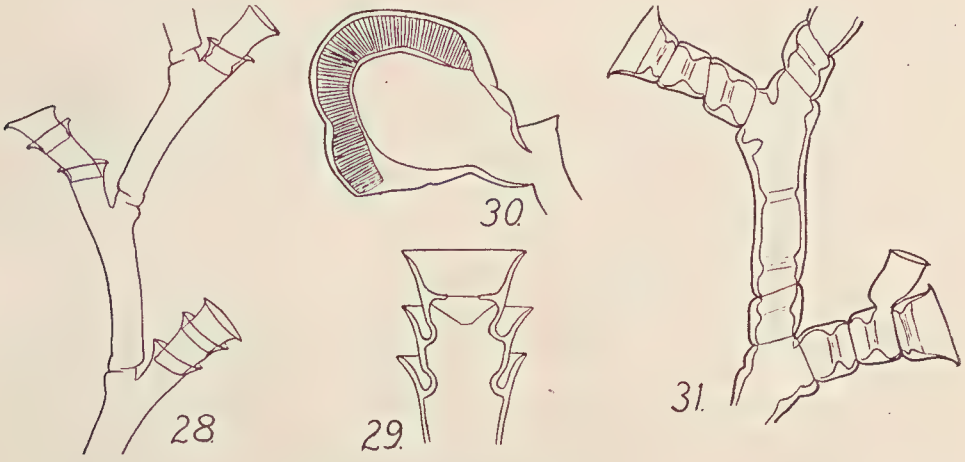
Locality: Eaglehawk Neck (February, 1948); Seven miles east of C. Pillar, 100 fathoms (Briggs); Ten miles north of Circular Head (Bale).

Distribution: Recorded from Station 145, off Marion Island, 50 fathoms (Allman); Station 312, Port Famine, Patagonia, Lat. 53° 37′ 30″ S., Long. 70° 65′ W., 9 fathoms (Allman); Port Stephens; Port Jackson; Bondi, N.S.W. (Bale); Gulf of Manaar, Ceylon (Thornely); Station 44, off Coogee, N.S.W., 49-50 fathoms (Ritchie).

The specimen agrees with that described by Bale (1888, p. 759) in its small size and monosiphonic habit. Allman's original description of the species was of a large form 10 cm. high, and polysiphonic at the base of the stem. The species described in present paper was originally named *Halecium gracile* by Bale, but was subsequently shown to be identical with *Halecium flexile* Allman.

A single hydrophore arises primarily from each internode, but with increasing age it may be regenerated three or four times, the point of origin being on or near the diaphragm of the preceding one.

The refractile puncta near the rim of the hydrophore, noted by Bale (1888, p. 760), have not been observed in any of the specimens in this collection. The polypite is connected with the coenosarc by a narrow neck, or strand, a characteristic feature of the Campanulariidae.



FIGS 28-31.

Halecium flexile Allman. Fig. 28: Portion of colony. Fig. 29: Longitudinal section through three hydrophores showing method of regeneration. Fig. 30: Gonotheca. *Phylactotheca armata* Stechow. Fig. 31: Portion of colony.

Genus **Phylactotheca** Stechow, 1913

Stem, when present regularly jointed, hyaline, monosiphonic; hydrotheca completely free, strictly alternate, bell-like. Hydranth large, similar to Halecium. Hypostome conical. Nematophores monothalamic, unmoveable, bell-shaped.

This generic description is modified from that of Stechow (1913, p. 155) by the omission of the words 'without basal-chamber' in the description of the hydrotheca. *Phylactotheca pacifica*, the species for which Stechow erected the genus, lacked a diaphragm in the hydrophore. However, *P. armata* Stechow possesses a diaphragm, and Stechow failed to alter his generic description to accommodate this feature.

Phylactotheca armata Stechow, 1924

(Fig. 31)

Phylactotheca armata Stechow, 1924.
Ophiodissa fragilis Blackburn, 1937a, b.

Trophosome: Hydrocaulus monosiphonic, occasionally branched, attaining a height of about 2 cm.; stem consists of alternate long and short internodes with oblique joints, and with the perisarc thickened into annuli which form partial cross-septa; the long internodes bear pedicellate hydrophores near their distal ends, the arrangement being alternate; pedicels consist of one to three segments and appears to be formed by differentiation during growth of hydrophores. Hydrophores borne terminally, one on a pedicel, free, bell-shaped, as deep as wide, margin entire and everted; a delicate septum is present about one-third of length from base, and on this the hydranth rests. Sarcothecae, single-chambered, large,

fixed, with an everted margin. They occur one or two on the stem, but more often in association with a hydrophore, in which case a single one arises from a segment of the pericel. Not all Hydrophores have these accosiated sarcothecae, there often being only one or two on the whole colony.

Gonosome: Gonothecae sub-spherical, arising at the junction of stem and hydrorhiza, or stem and pedicel.

Dimensions:

Hydrocaulus internode (long), length	0·33-0·47 mm.
Hydrocaulus internode (short), length	0·08-0·10 mm.
Hydrocaulus internode, diameter	0·12-0·13 mm.
Hydrophore, depth	0·12-0·13 mm.
Hydrophore, breadth at aperture	0·18-0·25 mm.
Sarcotheca, length	0·13-0·15 mm.
Sarcotheca, diameter at aperture	0·10 mm.

Locality: Bicheno (May, 1949).

Distribution: Champion Bay, W.A. (Stechow); Lady Julia Percy Island (Blackburn).

The specimen in this collection, on which the above description is based, was taken from storm-drifted sea-weed. It consists of a number of upright shoots, not more than 1·5 cms. high; only one of the shoots bearing a short lateral branch. The gonosome was not present.

Stechow (1924, p. 59) states that sarcothecae occur on the stem as well as in association with the hydrophores. In none of the present specimens, however, are there cauline sarcothecae. This may be due to injury.

Family SYNTHECIDAE

Genus **Synthecium** Allman, 1876

'Hydrocaulus divided into definite internodes, each internode carrying a pair of opposite hydrothecae, or a single hydrotheca which alternates with those of the internodes on each side of it. Hydrothecae adnate to a greater or less extent to the internode.

Gonangia borne on peduncles which spring from within the cavity of certain hydrothecae, where they take the place of the hydranths'. — Allman.

Synthecium patulum (Busk, 1852)

(Figs 32, 33)

Sertularia patula Busk, 1852.
Sertularia orthogonia Busk, 1852.
Synthecium patulum Bale, 1888.

Trophosome: Hydrocaulus monosiphonic, pinnately or bipinnately branched, attaining a height of about 4 cm.; stem jointed; internodes long, each bearing a single pair of hydrothecae near the middle, and a pair of opposite pinnae near the distal end; pinnae distant, at an angle of about 70° to stem axis, internodes each bearing one pair of hydrothecae. Hydrothecae opposite, not in contact with each other, tubular, adnate about three-quarters of length; free portion divergent, ascending; aperture circular, with margin entire, sinuated, slightly everted and regenerated one or twice.

Dimensions:

Hydrocaulus internode, length	2·00-2·33 mm.
Hydrocaulus internode, diameter	0·30-0·33 mm.
Pinna internode, length	0·66-0·71 mm.
Hydrotheca, length	0·50-0·58 mm.
Hydrotheca, length (free portion)	0·17-0·20 mm.
Hydrotheca, diameter at aperture	0·17-0·18 mm.

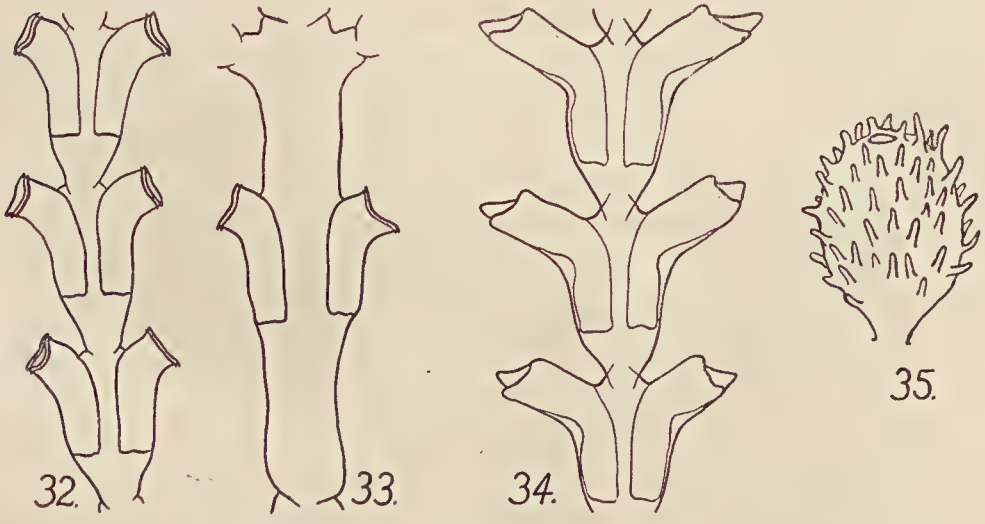
Locality: D'Entrecasteaux Channel; Bass Strait (Busk).

Distribution: Recorded from Williamstown, Victoria; Queenscliff, Victoria (Bale); Mouth of Snowy River (MacGillivray).

The example, from D'Entrecasteaux Channel, was found growing in association with *Halecium fragile* n.sp. attached to the shell of the Commercial Scallop *Notovola fumatus*.

In common with most other species of *Synthecium* the two hydrothecae forming the proximal pair on any pinna, are dissimilar. The base of the upper one is closer to the stem axis, and the free portion of the adcauline wall is markedly shorter than that of the others on the pinna.

In the absence of the gonosome it is not known whether the specimen is male or female. Totton (1930, p. 68) states: 'There is reason to believe that the dimensions of the male and female specimens of any species are different, the female being sometimes the larger and somtimes the smaller'.



Figs 32-35.

Synthecium patulum (Busk). Fig. 32: Portion of pinna. Fig. 33: Stem internode, with single pair of hydrothecae, and single pair of pinnae. *Diphasia sub-carinata* (Busk). Fig. 34: Portion of colony, with paired hydrothecae. Fig. 35: Gonotheca.

Family SERTULARIIDAE

'Hydrothecae perfectly sessile, more or less inserted in the stem and branches; polypites wholly retractile, with a single wreath of filiform tentacles around a conical proboscis; gonozooids always fixed'. — Hincks.

The classification of this family is still under review, there being disagreement among taxonomists as to generic characters.

Prior to 1893 there was general agreement that the basis for separation of genera was the method of arrangement of hydrothecae. However, Levinsen, in 1892, put forward the view that generic separation should depend on the opercular structure, associated with the condition of the hydrotheca margin.

Genus **Selaginopsis** Allman, 1877

'Hydrophyton consisting of a single axile tube, to which the hydrothecae are adnate, and on which they are disposed in several longitudinal rows'. — Allman.

Selaginopsis dichotoma (Allman, 1888)

Dictyocladium dichotomum Allman, 1888.
Selaginopsis dichtoma Billard, 1910.

Trophosome: Hydrocaulus branching, monosiphonic, attaining a height of about 10-12 cm.; jointing distinct at branch origins, but obscure elsewhere; branching dichotomous, in one plane, with branches anastomosing to form a net. Hydrothecae tubular, stout, divergent, adnate for most of length; margin of aperture with three deep emarginations, often regenerated (five or six times); operculum of three valves; hydrothecae arranged spirally in four longitudinal series.

Gonosome: Gonothecae erect, large, ellipsoid, axially placed and arising from the inner side of a branch just above origin; 'encircled by a very wide spiral wing the perisarc of which is double'. Bale (1915, p. 265); aperture tubular, slightly expanding.

Locality: Off South Cape, 75 fathoms (Bale); Thirty-five miles south-east of Bruni Island, 150-230 fathoms (Bale); Station 162, off East Moncoeur Island, Bass Strait, 38-40 fathoms (Allman).

Dimensions are not given. There is no specimen in this collection.

Genus **Diphasia** L. Agassiz, 1862

'Zoophyte plant-like, stem more or less branching, jointed, rooted by a creeping stolon; hydrothecae opposite, a pair on each internode, occasionally sub-alternate, with an internal valve-like operculum; gonothecae scattered, differently shaped in the two sexes—the female ample, more or less cleft or divided into segments above, containing a marsupial chamber; the male smaller, with a central tubulous aperture'. — Hincks.

Diphasia sub-carinata (Busk, 1852)

(Figs 34, 35)

Sertularia sub-carinata Busk, 1852.
Diphasia sub-carinata Bale, 1884.

Trophosome: Hydrocaulus monosiphonic, attaining a height of about 5 cm.; stem simple, or with irregular, pinnately disposed branchlets; a single pair of hydrothecae on each internode. Hydrothecae opposite, long, tubular, somewhat expanded upwards, upper half widely divergent, not in contact with each other; aperture large, with an internal operculum, and with three large, blunt marginal lobes, two laterals, and one external and inferior.

Gonosome: Gonothecae borne on the lower part of the hydrocaulus in one or two rows; ovate, with a narrow tubular orifice; the surface is covered with small curved spines, except for an area near the stalk, and for most of the side which is adpressed to the hydrocaulus.

Dimensions:

Hydrocaulus internode, length	0·80-0·83 mm.
Hydrotheca, length adnate	0·49-0·55 mm.
Hydrotheca, length free	0·49-0·51 mm.
Hydrotheca, diameter of free portion	0·20-0·25 mm.
Gonotheca, length	up to 1·00 mm.
Gonotheca, diameter	0·60 mm.

Locality: Bicheno (May, 1949); Bass Strait (Busk); Off Devonport and Launceston (Bale); Twenty miles east of King Island, Bass Strait (Bale).

Distribution: Recorded from Port Stephens (Haswell); Griffiths' Point (Goldstein); Portland (Maplestone); Queenscliff; Williamstown; Great Australian Bight, 40-100 fathoms (Bale); Forty miles west of Kingston, S.A., 30 fathoms (Bale).

The specimen consists of a number of reddish-brown shoots arising from a colourless hydrorhiza, growing on the holdfast of storm-drifted *Macrocystis*.

Bale (1884, p. 103) mentions the presence of a keel, or ridge, running down the front of the hydrotheca. This however, is not present on any of the specimens in this collection.

Genus **Sertularia** Linné, 1758 (in part)

'Zoophyte plant-like; stems simple or branching, jointed, rooted by a creeping stolon; hydrothecae biserial, opposite to alternate, without external operculum, mostly arranged in pairs; gonothecae scattered, with a simple orifice, and without an internal marsupium'. — Bale.

Key to the Genus Sertularia

1.	Hydrothecal margin with two teeth	4
	Hydrothecal margin with more than two teeth	2
2.	Hydrotheca with three teeth	*S. tridentata* Busk
	Hydrotheca with more than three teeth	3
3.	Pinnae alternate; hydrothecal margin with six teeth	*S. elongata* Lamouroux
	Pinnae opposite; hydrothecal margin with about six teeth	*S. insignis* Thompson
4.	Hydrocaulus short (1-2 cm.), simple	5
	Hydrocaulus branched (not pinnately)	6
	Hydrocaulus pinnately branched; pinnae alternate, one on an internode; hydrothecae opposite to alternate	7
5.	Hydrothecae adnate to margin or nearly so	*S. minima* Thompson
	Hydrothecae adnate about one-half of length, short and squat	*S. loculosa* Bale
6.	Branching dichotomous; hydrothecae opposite, adnate to margin, not in contact	*S. operculata* Linné
	Branching rare; hydrothecae opposite, tubular, adnate about two-thirds length, in contact in front but not behind	*S. pusilla* Bale
7.	Hydrothecae ovato-conic	*S. penna* Kirchenpauer
	Hydrothecae sub-tubular (flask-shaped)	8
	Hydrothecae tubular	9
8.	Hydrothecae with a strong tooth projecting inwards from abaxial marginal wall	*S. macrocarpa* Bale
	Hydrothecal marginal teeth laterally placed, equal	*S. australis* Kirchei
	Hydrothecal marginal teeth unequal, one small in front, other larger in outer angle	*S. pulchella* Thompson
9.	Hydrothecae with an internal process arising from middle of abaxial wall	*S. maplestonei* Bale
	Hydrothecae (pinnate) adnate for half-length, projecting forward; hydrothecae in contact for two-thirds length	*S. geminata* Bale
	Hydrothecae (pinnate) adnate or immersed, teeth large, lobate, outer recurved	*S. unguiculata* Busk

Sertularia operculata Linné, 1758

(Figs 36, 37)

Sertularia operculata Linné, 1758.
Sertularia usneoides Pallas, 1766.
Nigellastrum usneoides Oken, 1815.
Sertularia serra Lamarck, 1816.
Dynamena serra Blainville, 1834.
Dynamena brevicella Lamouroux, 1824b.
Sertularia brevicella Milne-Edwards, 1836.
Dynamena operculata Lamouroux, 1816.
Amphisbetia operculata L. Agassiz, 1862.
Dynamena fasciculata Kirchenpauer, 1864.
Odontotheca operculum Levinsen, 1913.
?Dynamena pulchella D'Orbigny, 1839-1846.
?Sertularia pulchella Nutting, 1904.
?Sertularia crinis Allman, 1886.

Trophosome: Hydrocaulus slender, monosiphonic, attaining a height of about 20 cm., much branched dichotomously, bearing a pair of opposite hydrothecae on each internode. Hydrothecae tubular, adnate to the margin or nearly so, not in contact with each other; aperture with a small spine-like tooth in front, and a larger tooth on the posterior, outer side, the latter usually slightly incurved.

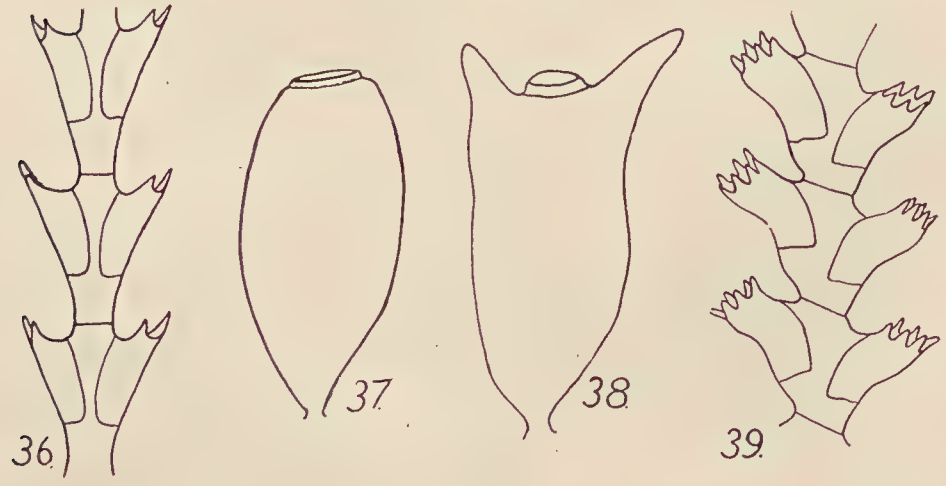
Gonosome: Gonothecae obovate, smooth, large, with an elevated collar around the aperture which is operculate.

Dimensions:

Hydrocaulus internode, length	0·50-0·55 mm.
Hydrotheca, length	0·30-0·32 mm.
Hydrotheca, diameter	0·13-0·15 mm.
Gonotheca, length	up to 1·50 mm.
Gonotheca, diameter	up to 0·75 mm.

Locality: D'Entrecasteaux Channel (August, 1949); Seven miles east of Cape Pillar, 100 fathoms (Briggs); Devonport; near Circular Head (Bale).

Distribution: Cosmopolitan.



Figs 36-39.

Sertularia operculata Linnaeus. Fig. 36: Portion of colony. Fig. 37: Gonotheca. *Sertularia elongata* Lamouroux. Fig. 38: Gonotheca. Fig. 39: Portion of colony.

In the specimens in this collection the joints of the hydrocaulus are not visible other than as constrictions below the hydrothecae.

This species is very abundant in the D'Entrecasteaux Channel, being constantly taken in the form of large tangled masses, in scallop dredges.

Sertularia elongata Lamouroux, 1816

(Figs 38, 39)

Sertularia elongata Lamouroux, 1816.
Sertularia scandens Lamouroux, 1816.
Sertularia lycopodium Lamarck, 1816.
Sertularia millefolium Lamarck, 1816.
Dynamene abietinoides Gray, 1843.
Sertularia abietinoides Hutton, 1872.

Trophosome: Hydrocaulus monosiphonic, flexuous, pinnately or bipinnately branched, attaining a height of about 7-8 cm.; each stem internode bears a pinna, an axillary hydrotheca, and a pair of hydrothecae above; pinnae alternate, internodes bearing one or more pairs of hydrothecae. Hydrothecae sub-alternate, not in contact, tubular, divergent, adnate about half length, margin of aperture with six spine-like teeth.

Gonosome: Gonothecae on the stem or pinnae, large, pyriform, sides produced into two erect spine-like processes extending above aperture; aperture with tubular neck, and an operculum.

Dimensions:

Hydrocaulus internode, length	up to 0·80 mm.
Pinna internode, length	0·44-0·50 mm.
Hydrotheca, length	0·30-0·33 mm.
Hydrotheca, diameter	0·16-0·20 mm.
Gonotheca, length	2·32 mm.
Gonotheca, length excluding spines	2·00 mm.
Gonotheca, breadth	0·83 mm.

Locality: D'Entrecasteaux Channel; Oyster Bay (May, 1949); Devonport; Bass Strait.

Distribution: Recorded from South Australia; Victoria; New Zealand.

The specimen from Oyster Bay, the basis of the above description consists of a number of dark brown colonies which were taken from storm-drifted seaweed. All the specimens were incomplete due to injury.

Sertularia minima Thompson, 1879

(Figs 41, 42)

Synthecium gracilis Coughtrey, 1874.
Sertularia pumila Coughtrey, 1875.
Sertularia minima D'A. W. Thompson, 1879.
Sertularia pumiloides Bale, 1881.
?Sertularia crinoidea Allman, 1886.
Odontotheca minima Levinsen, 1913.

Trophosome: Hydrocaulus simple, monosiphonic, attaining a height of about 1·5 cm., divided into regular internodes by oblique joints, each internode with a pair of hydrothecae. Hydrothecae opposite, tubular, in contact or approximate in front, but separate behind, adnate for most of length, upper half divergent; aperture looking upwards and outwards, margin with two lateral teeth, the outer the larger.

Gonosome: Gonothecae obovate, elongate, with margin of aperture elevated into a collar; aperture operculate.

Dimensions:

Hydrocaulus internode, length	0·42-0·43 mm.
Hydrocaulus internode, diameter	0·22-0·25 mm.
Hydrotheca, length	0·22-0·23 mm.
Hydrotheca, diameter	0·13-0·15 mm.
Gonotheca, length	up to 1·25 mm.
Gonotheca, diameter	up to 0·66 mm.
Gonotheca, diameter of aperture	0·30 mm.

Locality: South Arm, Derwent Estuary (July, 1947); Eaglehawk Neck (February, 1948); Rheban (May, 1949); Oyster Bay (May, 1949).

Distribution: Recorded from New Zealand (Coughtrey); Gulf of St. Vincent (Thompson); Portland (Maplestone); Williamstown; Queenscliff; Great Australian Bight (Bale).

The specimens in this collection were taken from storm-drifted seaweed, and from *Macrocystis* growing near low-tide level. The majority of specimens do not exceed 1 cm. in height.

Bale (1915, p. 270-272) discusses the presence, in both this species and *Sertularia pusilla*, of minute tubular appendages near the base of some of the internodes; the presence of these tubular 'sarcothecae' has also been noted by Mulder and Trebilcock (1914b, p. 39). However, in none of the numerous specimens in this collection is there any structure comparable to the 'sarcothecae' described or figured by the above authors.

There is a considerable range of size and shape, the dimensions quoted being for one of the most typical forms.

Sertularia pusilla Bale, 1915

(Fig. 40)

Sertularia minima Thompson, var. *tubatheca* Mulder and Trebilcock, 1914b.
Sertularia pusilla Bale, 1915.
Not *Sertularia tubitheca* Allman, 1877.

Trophosome: Hydrocaulus sparingly branched or simple, monosiphonic, attaining a height of about 1 cm., usually divided into internodes, each of which bear a pair of hydrothecae, but in some cases the joints may be lacking on part or all of the stem. Hydrothecae opposite, tubular, in contact or approximate in front, but separate behind, adnate for about two-thirds of length, upper half moderately divergent; aperture margin with two lateral lobes, or teeth, the outer the larger.

Gonosome: Gonothecae borne singly on the proximal internode of the shoot; ovate, somewhat compressed, the margin elevated to form a low collar with minute internal denticles.

Dimensions:

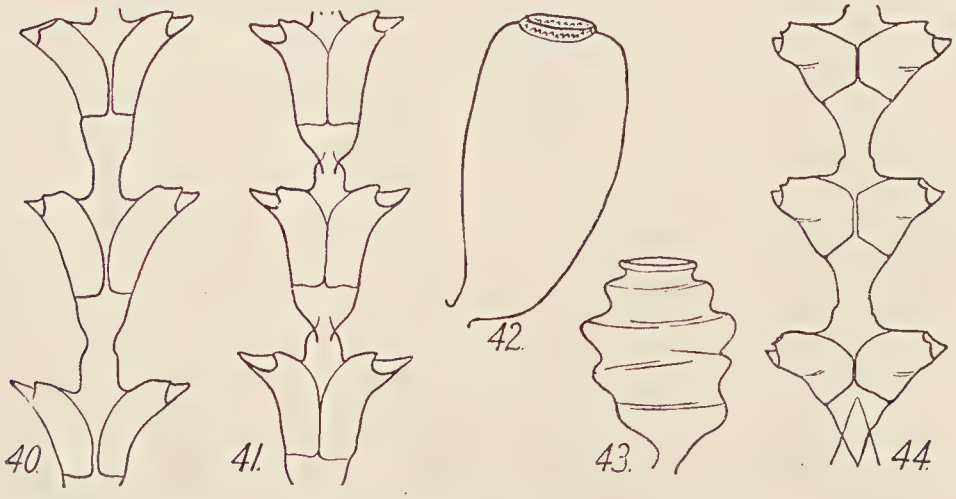
Hydrocaulus internode, length	0·33-0·45 mm.
Hydrocaulus internode, diameter	0·05-0·07 mm.
Hydrotheca, length	0·23-0·25 mm.
Hydrotheca, diameter at aperture	0·07-00·8 mm.

Locality: South Arm, Derwent Estuary (April, 1947); Bicheno (May, 1949); Devonport and Launceston (Bale); Bass Strait (August, 1949).

Distribution: Recorded from Queenscliff (Mulder and Trebilcock); Victoria.

The specimens in this collection were taken from *Macrocystis* stipe, near low-tide level (South Arm); and from storm-drifted material (Bicheno). The specimen from Bass Strait, growing epizoically on a pleopod of *Jasus lalandii*, consisted of a single colony bearing shoots about 5 mm. high.

The minute tubular 'sarcothecae' described by Bale (1915, p. 270), have not been observed.



FIGS 40-44.

Sertularia pusilla Bale. Fig. 40: Portion of colony. *Sertularia minima* Thompson. Fig. 41: Portion of colony. Fig. 42: Gonotheca. *Sertularia loculosa* Bale. Fig. 43: Gonotheca. Fig. 44: Portion of colony.

Sertularia loculosa Bale, 1884

(Figs 43, 44)

Sertularia loculosa Bale, 1884.
Sertularia turbinata Billard, 1910.
?*Sertularia turbinata* Ritchie, 1910.
Not *Sertularia loculosa* Busk, 1852.
Not *Dynamena turbinata* Lamouroux, 1816.

Trophosome: Hydrocaulus simple, monosiphonic, attaining a height of about 1-2 cm., divided into internodes; joints either single and horizontal, or double, the lower being horizontal, the upper very slender and oblique. Hydrothecae in pairs, short and squat, opposite, in contact in front but not behind, adnate about one-half length; upper half markedly divergent, with angle of flexure appearing as a nearly horizontal fold; base very oblique; aperture contracted, directed outwards and upwards, margin with two lateral teeth.

Gonosome: Gonothecae borne on the proximal internodes of the hydrocaulus; ovate, truncate, with strong transverse rugae; aperture large, operculate.

Dimensions:

Hydrocaulus interdode, length	0·55-0·58 mm.
Hydrotheca, length	0·28-0·30 mm.
Hydrotheca, diameter	0·20-0·22 mm.
Hydrotheca, diameter at aperture	0·12-0·13 mm.

Locality: Bicheno (May, 1949); Bass Strait, 45 fathoms (Busk).

Distribution: Recorded from Portland (Maplestone); Queenscliff.

The specimen, which is the basis of this description, lacks gonothecae. The oblique joints between the internodes are marked, but the single, horizontal joints are rather obscure, the appearance being of long internodes bearing several pairs of hydrothecae.

The specimen was found growing on storm-drifted *Macrocystis*.

Sertularia unguiculata Busk, 1852

(Figs 45, 46)

Sertularia unguiculata Busk, 1852.
Sertularia sp.? Coughtrey, 1876.
Thuiaria ambigua Thompson, 1879.
Desmoscyphus unguiculata Allman, 1886.
Dynamena australis Kirchenpauer, 1864.
Sertularia australis Thompson, 1879.
Desmoscyphus pectinatus Allman, 1888.
Sertularia Challengeri Nutting, 1904.
?Thuiaria heteromorpha Allman, 1886.
Not *Sertularia australis* Bale, 1886.

Trophosome: Hydrocaulus monosiphonic, pinnately branched, attaining a height of about 15 cm.; stem divided into long and short internodes; long internodes bear a pinna with two hydrothecae above and one below on one side. and a pinna with three hydrothecae above on the other; short internodes bear a pinna, an axillary hydrotheca, and a pair of hydrothecae above. Pinnae alternate, proximal internodes may be long bearing several pairs of hydrothecae, the distal internodes usually short with one or two pairs. Hydrothecae tubular, subalternate on the stem, opposite on the pinnae, upper portion free, divergent, directed towards the front, lower portion adnate, often immersed; hydrothecae on pinnae in contact or approximate in front, separate behind; aperture oval, small, margin with two large lateral teeth, the outer recurved.

Gonosome: Gonothecae borne on the hydrocaulus, large, obovate, aperture operculate, with a low collar.

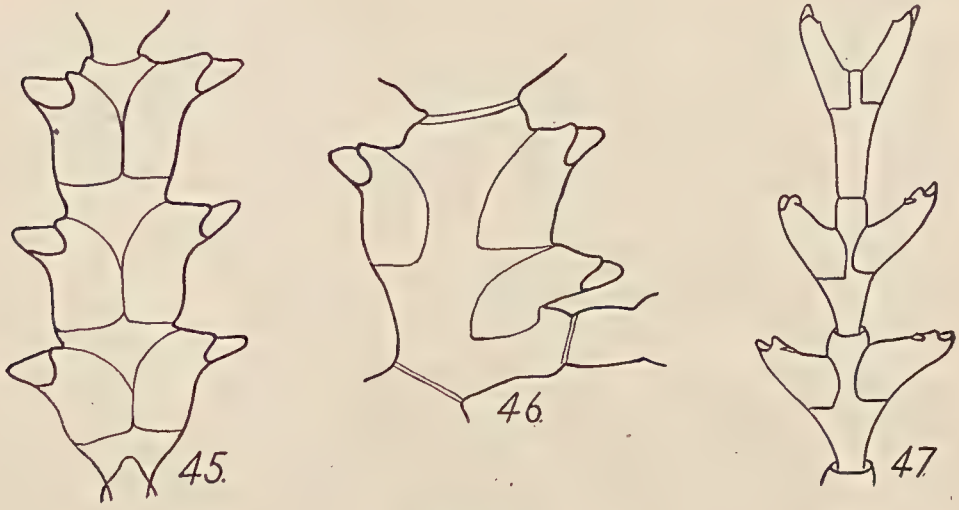
Dimensions:

Hydrocaulus internode (long), length	1·08 mm.
Hydrocaulus internode (short), length	0·58-0·65 mm.
Pinna internode, length (4 pairs thecae)	1·16-1·22 mm.
Pinna internode, length (3 pairs thecae)	0·96-1·00 mm.
Pinna internode, length (2 pairs thecae)	0·73-0·78 mm.
Pinna internode, length (1 pair thecae)	0·38-0·41 mm.
Hydrotheca, length	0·22-0·25 mm.
Hydrotheca, breadth (frontal aspect)	0·10-0·12 mm.
Hydrotheca, breadth (lateral aspect)	0·16-0·18 mm.

Locality: Oyster Bay (May, 1949); Ten miles north of Circular Head (Bale); Bass Strait (Bale).

Distribution: Recorded from Portland (Maplestone); Griffiths' Point (Goldstein); Queenscliff; New Zealand; Robe, S.A. (Smeaton); Sydney (Maplestone).

According to Bale (1914b, p. 16-19) this species is very variable, both in size (from 2 cm. to 15 cm.) and in form. The specimens in this collection, from Oyster Bay, are all under 3 cm. in length, and were taken from storm-drifted kelp.



FIGS 45-47.

Sertularia unguiculata Busk. Fig. 45: Portion of branch. Fig. 46: Stem internode. *Sertularia macrocarpa* Bale. Fig. 47: Portion of colony (after Bale).

Sertularia macrocarpa Bale, 1884

(Fig. 47)

Sertularia macrocarpa Bale, 1884.
Odontotheca macrocarpa Levinsen, 1913.

Trophosome: Hydrocaulus slender, flexuous, monosiphonic, pinnately branched, attaining a height of about 12-15 cm.; stem jointed, each internode bearing a branch, an axillary hydrotheca, and a pair of hydrothecae above; branches alternate, internodes with one or two pairs of hydrothecae. Hydrothecae flask-shaped or sub-tubular, opposite to sub-alternate, in contact in front but not behind, adnate for about one-half length, upper side of free part nearly horizontal except towards distal end of branch where free part is elongated and produced upwards; aperture small, facing upwards, margin with two rounded lateral teeth, and a tooth projecting inwards from the adaxial wall.

Gonosome: Gonothecae large, obovate, borne in rows on the stem; aperture operculate with a low collar.

Locality: Bass Strait (Bale).

Distribution: Recorded from Queenscliff; Williamstown; Portland (Maplestone).

Dimensions are not given. There is no specimen in this collection.

Sertularia pulchella Thompson, 1879

(Fig. 48)

Sertularia pulchella D'A. W. Thompson, 1879.
?Sertularia bicuspidata Lamarck, 1816.

Trophosome: Hydrocaulus slender, flexuous, monosiphonic, pinnately branched, attaining a height of about 1-2 cm.; stem internodes each bearing a pinna, an axillary hydrotheca, and a pair of hydrothecae above; pinnae alternate, internodes with one to three pairs of hydrothecae. Hydrothecae flask-shaped, with upper wall horizontal, opposite to alternate, approximate or in contact in front, adnate about one-half length; a small process projects into cell from abaxial wall, a little above the base; aperture small, looking upwards, margin with two spine-like teeth, one anterior, and one on posterior outer angle.

Gonosome: Gonothecae pyriform, large, with sides produced into two large, erect, conical proceses extending above aperture which is operculate and has a low collar. Gonothecae borne singly near base of shoot.

Locality: George Town (Thompson).

Distribution: Recorded from South Australia (Smeaton).

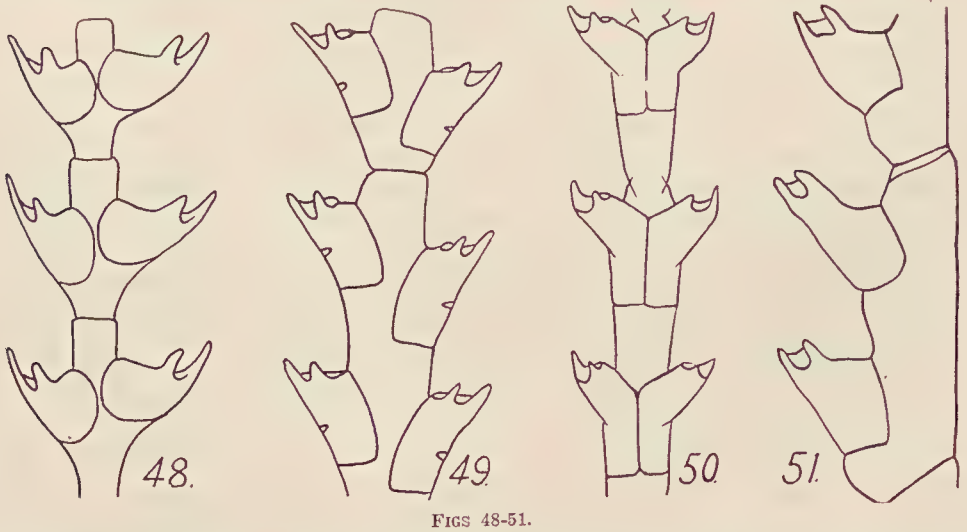
Dimensions are not given. There is no specimen in this collection.

Sertularia maplestonei Bale, 1884

(Fig. 49)

Sertularia maplestonei Bale, 1884.
Odontotheca maplestonei Levinsen, 1913.
Not *Thuiaria maplestonei* Billard, 1907.

Trophosome: Hydrocaulus monosiphonic, slender, pinnately branched, attaining a height of about 6-8 cm.; stem divided into internodes each bearing a pinna, an axillary hydrotheca, and a pair of hydrothecae above; pinnae alternate, internodes diminishing in length from the proximal, each internode with from one to



FIGS 48-51.

Sertularia pulchella Thompson. Fig. 48: Portion of colony. *Sertularia maplestonei* Bale. Fig. 49: Portion of colony. *Sertularia geminata* Bale. Fig. 50: Portion of stem in frontal aspect (after Bale). Fig. 51: Portion of stem in lateral aspect (after Bale).

five pairs of hydrothecae. Hydrothecae tubular, divergent, sub-alternate, not in contact with one another, adnate nearly to margin, free portion short; a small process projects into cell from middle of the abaxial wall; aperture facing upwards, margin with two teeth, one anterior, the other at the posterior outer angle.

Gonosome: Gonothecae elongate, sub-tubular, produced into two angular processes at the sides of the aperture; aperture operculate, margin elevated into a low collar.

Locality: Hunter Group, Bass Strait, 15 fathoms (Bale).

Distribution: Recorded from Portland (Maplestone); Victoria (Marktanner-Turneretscher).

Dimensions are not given. There is no specimen in this collection.

Sertularia geminata Bale, 1884

(Figs 50, 51)

Sertularia geminata Bale, 1884.
Desmoscyphus orifissus Allman, 1886.

Trophosome: Hydrocaulus monosiphonic, branched, slender, attaining a height of about 10-12 cm.; stem internodes each with a pinna, an axillary hydrotheca, and a pair of hydrothecae above; pinnae alternate, attached to the stem by an oblique joint, internodes variable in length, the proximal ones longest, bearing three to four pairs of hydrothecae. Hydrothecae tubular, divergent in the upper half; sub-alternate on the stem, opposite on the pinnae; those on pinnae in contact with one another for about two-thirds of length, and adnate for about one-half length to pinna from which they project forwards; aperture oval, small, facing upwards and outwards, margin with two incurved, lateral teeth.

Gonosome: Gonothecae ovate, borne on the stem and pinnae; aperture operculate with a low collar.

Locality: Twenty miles east of King Island, Bass Strait (Bale).

Distribution: Recorded from Portland (Maplestone); Queenscliff; South coast of South Australia (Bale).

Dimensions are not given. There is no specimen in this collection.

Sertularia insignis Thompson, 1879

(Fig. 52)

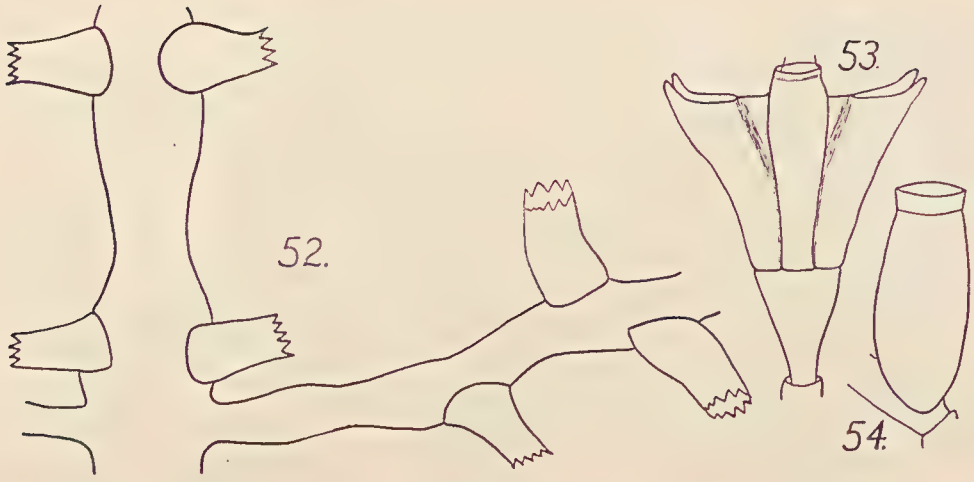
Sertularia insignis D'A. W. Thompson, 1879.

Trophosome: Hydrocaulus monosiphonic, pinnately branched, attaining a height of about 16-18 cm.; pinnae opposite; jointing obscure on both stem and pinnae. Hydrothecae tubular, elongate, tapering slightly towards aperture the margin of which is furnished with about six small, rounded teeth; hydrothecae opposite on stem, at 90° to axis, alternate to sub-alternate on pinnae, at about 80° to axis.

Gonosome: Gonothecae large, elongate, oblong, with two blunt divergent spines at the upper angles; aperture small; gonothecae arise from pinnae close to their origin.

Locality: George Town (Harvey).

Dimensions are not given. There is no specimen in this collection.



FIGS 52-54.

Sertularia insignis Thompson. Fig. 52: Portion of colony (after Bale). *Sertularia penna* (Kirchenpauer). Fig. 53: Internode of stem (after Bale). Fig. 54: Gonotheca (after Bale).

Sertularia penna (Kirchenpauer, 1864)

(Figs 53, 54)

Dynamena penna Kirchenpauer, 1864.
Sertularia penna Bale, 1884.

Trophosome: Hydrocaulus monosiphonic, pinnately branched, attaining a height of about 6-8 cm.; stem internodes each bearing a pinna, an axillary hydrotheca, and a pair of hydrothecae above; pinnae alternate. Hydrothecae opposite, obconical, adnate to the margin or nearly so; aperture large, facing upwards and outwards, margin with two lateral spine-like teeth.

Gonosome: Gonothecae small, cylindrico-tubular, slightly contracted towards aperture which is expanding with a broad collar.

Locality: Bass Strait (Kirchenpauer).

Dimensions are not given. There is no specimen in this collection.

Sertularia australis (Kirchenpauer, 1864)

Dynamena australis Kirchenpauer, 1864.
Sertularia australis Thompson, 1879.

Trophosome: Hydrocaulus short, slender, monosiphonic, pinnately branched; stem internodes each bearing a pinna, an axillary hydrotheca, and a pair of hydrothecae above; pinnae alternate, internodes bearing one or two pairs of hydrothecae. Hydrothecae sub-alternate, those on pinnae in contact, adnate about one-half length, divergent, tapering slightly towards aperture which faces upwards and outwards; margin of aperture with two lateral teeth.

Gonosome: Gonothecae large, urceolate; aperture operculate with a low collar.

Locality: George Town (Thompson).

Distribution: Recorded from Port Phillip (Kirchenpauer, Thompson); Sealer's Cove; Cape Lefebvre.

Dimensions are not given. There is no specimen in this collection.

Sertularia tridentata Busk, 1852

Sertularia tridentata Busk, 1852.

Trophosome: Hydrocaulus monosiphonic, pinnately branched, attaining a height of about 5-6 cm.; branches borne on the middle 2 cm. of the stem, with those in the centre longer than those above and below. Hydrothecae urn-shaped, paired, opposite, divergent in the upper half, in contact in front, contracted towards the aperture; aperture entire, circular, looking upwards and outwards, margin with two long, slightly everted, lateral teeth, and one short, sharp superior tooth.

Locality: Bass Strait (Busk).

Dimensions are not given. There is no specimen in this collection.

Genus **Sertularella** Gray, 1843

'Zoophyte plant-like; stem simple or branching, jointed, rooted by a creeping stolon; hydrothecae biserial, decidedly alternate, one usually borne on each internode, with an operculum composed of several pieces, the orifice generally toothed; gonothecae usually ringed transversely'. — Bale.

Key to the Genus Sertularella

1.	Hydrothecae with three marginal teeth	2
	Hydrothecae with four marginal teeth	5
2.	Hydrothecae contracted towards aperture	*S. indivisa* Bale
	Hydrothecae not contracted towards aperture	3
3.	Hydrocaulus monosiphonic	4
	Hydrocaulus polysiphonic, hydrotheca adnate up to margin which may be regenerated	*S. adpressa* Ritchie
4.	Hydrocaulus simple, short (about 1 cm.)	*S. pygmaea* Bale
	Hydrocaulus pinnately, bipinnately, or irregularly branched	*S. divaricata* (Busk)
5.	Hydrocaulus simple, monosiphonic	6
	Hydrocaulus pinnately branched, polysiphonic	*S. tasmanica* Bale
6.	Hydrocaulus internodes undulated; hydrothecae squat, marginal teeth small, with shallow emarginations between	*S. undulata* Bale
	Hydrocaulus internodes smooth, twisted at joints; hydrothecae elongate, transversely rugose, contracted towards aperture	*S. robusta* Coughtrey

Sertularella indivisa Bale, 1881

(Figs 55, 56)

Sertularella indivisa Bale, 1881.
Sertularella solidula Bale, 1881.
Sertularella variabilis Bale, 1888.
Sertularella sieboldi Kirchenpauer, 1884.
*Sertularella müller*i Kirchenpauer, 1884.
Not *Sertularella indivisa* Stechow, 1913.

Trophosome: Hydrocaulus simple or pinnately branched, attaining a height of about 5 cm., divided into internodes by twisted joints, each internode bearing a hydrotheca, or a hydrotheca and a branch. Hydrothecae adnate for one-third to one-half length, divergent, transversely rugose (two or three ridges), becoming narrowed and contracted towards the aperture which is furnished with three marginal teeth, one superior and two laterals; operculum of three internal, compressed, vertical teeth, which alternate with the marginal ones.

Gonosome: Gonothecae three or four times the length of a hydrotheca, borne on hydrocaulus or hydrorhiza; ovate, with distinct transverse rugae, and with a tubular neck bearing on the summit three to six lobes or teeth.

Dimensions:

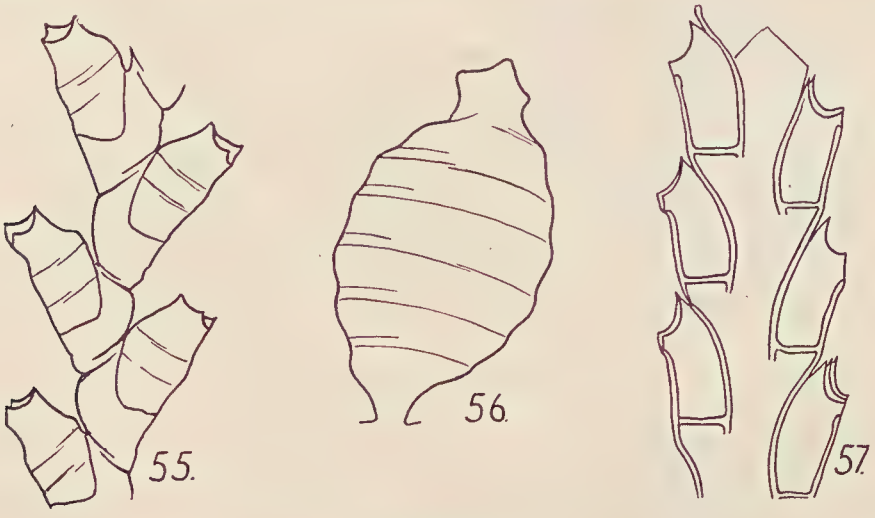
Hydrocaulus internode, length	very variable.
Hydrotheca, length	0·42-0·47 mm.
Hydrotheca, diameter	0·28-0·32 mm.
Hydrotheca, diameter at aperture	0·17-0·18 mm.
Gonotheca, length	up to 1·10 mm.
Gonotheca, diameter	up to 0·66 mm.

Locality: Adventure Bay (September, 1949); Blackman's Bay, Derwent Estuary (March, 1938); South Arm, Derwent Estuary (April, 1949); Eaglehawk Neck (February, 1948); Oyster Bay (May, 1949); Bass Strait (Bale).

Distribution: Recorded from South East Australia.

There is a wide range of variation among the specimens in this collection, some being profusely branched, others simple, some with rugose hydrothecae, others smooth. However, in nearly all cases the measurements agree over a narrow range.

The variations in this species have been discussed at length by Bale (1915, p. 285), and Hartlaub (1890, 1900, 1901), and in consequence *Sertularella indivisa*, *Sertularella solidula*, and *Sertularella variabilis* have been united in the one species.



Figs 55-57.

Sertularella indivisa Bale. Fig. 55: Portion of colony. Fig. 56: Gonotheca. *Sertularella adpressa* Ritchie. Fig. 57: Part of branch with hydrothecae (after Ritchie).

Sertularella adpressa Ritchie, 1911

(Fig. 57)

Sertularella adpressa Ritchie, 1911.

Trophosome: Hydrocaulus polysiphonic, profusely branched, attaining a height of about 10 cm.; main branches fascicled; stem and branches bear pinnae which are alternate, and in one plane; stem divided into regular internodes, joints oblique,

successively sloping in opposite directions; in pinnae the jointing becomes obscure. Hydrothecae tubular, adnate to the margin or nearly so; margin of aperture with three equal teeth, a superior and two laterals; margin often regenerated; an internal operculum of three pieces.

Gonosome: Gonothecae elongate, club shaped, sessile, smooth or weakly rugose; aperture small, margin elevated; borne immediately below a hydrotheca on stem, branches or pinnae, and lying closely pressed against the member.

Dimensions:

Hydrocaulus internode, length	up to 1·36 mm.
Pinna, diameter	0·42 mm.
Hydrotheca, length	0·42-0·43 mm.
Hydrotheca, diameter	0·19-0·21 mm.
Gonotheca, length	up to 2·00 mm.
Gonotheca, greatest breadth (frontal aspect)	0·64-0·71 mm.
Gonotheca, greatest breadth (lateral aspect)	0·52-0·64 mm.

Locality: Seven miles east of Cape Pillar, 100 fathoms (Briggs); Oyster Bay, 60 fathoms (Bale).

Distribution: Recorded from Station 36, of Botany Bay, N.S.W., 20-23 fathoms (Ritchie); Station 54, within Jervis Bay, N.S.W., 10-11 fathoms (Ritchie); Shoalhaven Bight, N.S.W., 15-45 fathoms (Bale).

The measurements quoted above are taken from Briggs (1914, p. 291), there being no specimen in this collection.

Sertularella robusta (Coughtrey, 1874)

(Fig. 58)

Sertularia simplex Coughtrey, 1874.
Sertularella robusta Coughtrey, 1875.
?Sertularella sp. Thompson, 1879.
?Sertularella microgona von Lendenfeld. 1884.
Sertularella angulosa Bale, 1894.
Not *Sertularella tenella* Alder, Hartlaub, 1901.

Trophosome: Hydrocaulus monosiphonic, simple, flexuous, attaining a height of about 1·5 cm.; stem divided by oblique joints into long internodes each bearing a hydrotheca near its distal end. Hydrothecae large, divergent, transversely rugose, adnate for about one-third of length, contracted towards the aperture, the margin of which is furnished with four teeth; operculum consists of three internal, vertical, compressed teeth.

Gonosome: Gonothecae ovate, transversely rugose, aperture with a toothed margin.

Dimensions:

Hydrocaulus internode, length	up to 1·00 mm.
Hydrocaulus internode, diameter at joint	0·08-0·10 mm.
Hydrotheca, length	0·43-0·47 mm.
Hydrotheca, length free	0·28-0·30 mm.
Hydrotheca, diameter at aperture	0·13-0·15 mm.
Hydrotheca, maximum diameter	0·22-0·23 mm.

Locality: D'Entrecasteaux Channel (April, 1947); Rheban (May, 1949).

Distribution: Recorded from Lyall Bay, New Zealand (Hutton); Otago (Coughtrey); Brown's River (Thompson); Port Phillip, Victoria (von Lendenfeld).

The specimens in this collection, the basis of the above description, consist of simple upright shoots not more than 1·5 cm. in height. The example from Rheban was taken from a piece of storm-drifted seaweed.

Sertularella undulata Bale, 1915

(Fig. 59)

Sertularella undulata Bale, 1915.

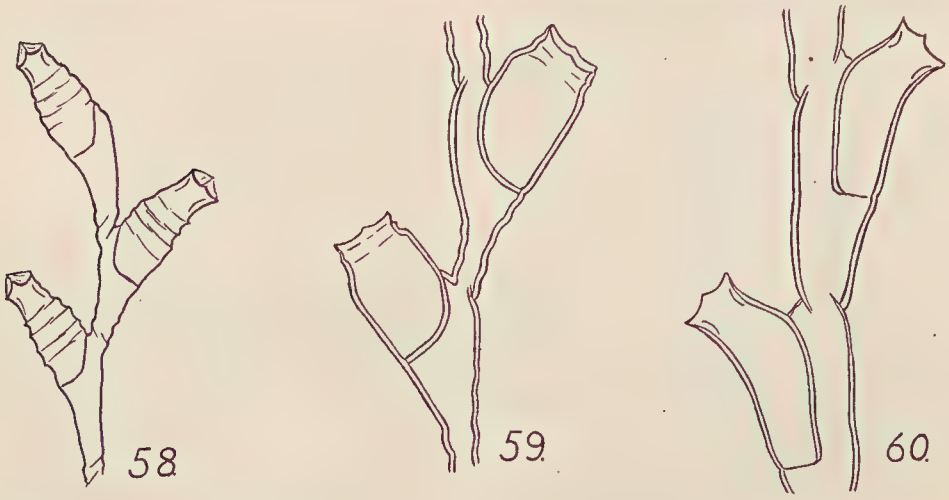
Trophosome: Hydrocaulus simple, monosiphonic, attaining a height of about 1 cm.; stem divided into internodes of variable length by twisted oblique joints; each internode bears a hydrotheca distally, the portion of internode below the hydrotheca being undulated. Hydrothecae short, squat, adnate about one-half length, proximal portion smooth, distal portion with a strong annular shoulder beyond which hydrotheca narrows and bears another smaller annulation close to the margin; aperture wide, square in outline, margin with four small teeth having between them shallow emarginations; no operculum.

Gonosome: Unknown.

Locality: Off South Cape, 75 fathoms (Bale).

The specimen, consisting of a single colony, was found growing epizoically on *Sertularella tasmanica* Bale.

Dimensions are not give. There is no specimen in this collection.



FIGS 58-60.

Sertularella robusta (Coughtrey). Fig. 58. Portion of colony. *Sertularella undulata* Bale. Fig. 59: Portion of colony (after Bale). *Sertularella tasmanica* Bale. Fig. 60: Portion of colony (after Bale).

Sertularella tasmanica Bale, 1915

(Fig. 60)

Sertularella tasmanica Bale, 1915.

Trophosome: Hydrocaulus polysiphonic, branched, attaining a height of about 3 cm.; branching irregularly pinnate, stem and branches divided into long internodes by twisted oblique joints; hydrothecae borne at distal end of internodes,

with branches arising below them; proximal branch internodes very long and may be slightly undulated at origin. Hydrothecae large, divergent, lying in one plane, adnate more than one-half length; expanded slightly towards aperture, margin with four teeth; operculum of three strong internal teeth.

Dimensions:

Stem internode, length below hydrotheca	about 0·45 mm.
Branch proximal internode, length below hydrotheca	up to 1·80 mm.
Hydrotheca, length	about 0·82 mm.

Locality: Off South Cape, 75 fathoms (Bale).

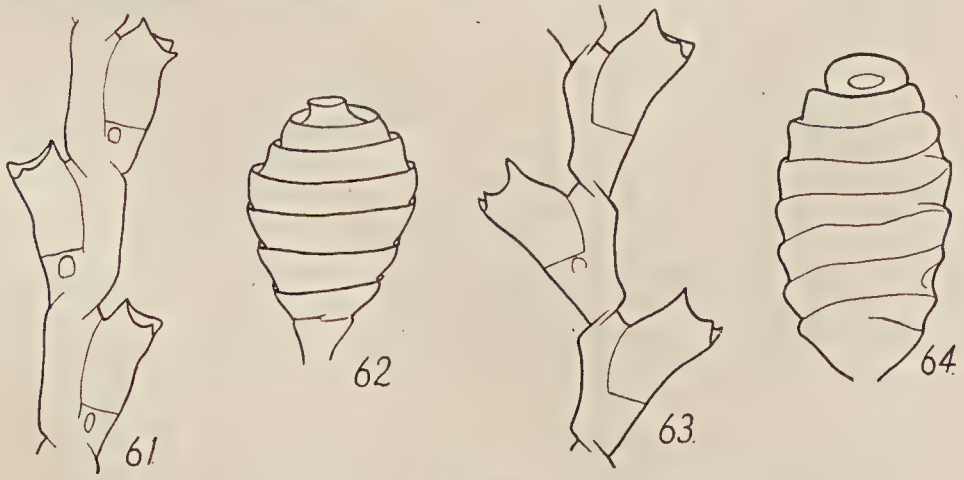
The dimensions given above are from the original specific description by Bale (1915, p. 283). There is no specimen in this collection.

Sertularella divaricata (Busk, 1852)

(Figs 61, 62)

Sertularia divaricata Busk, 1852.
Sertularella divaricata Bale, 1894.
Sertularella subdichotoma Kirchenpauer, 1884
Sertularella johnstoni Bale, 1884.
Not *Sertularella johnstoni* Gray, 1843.

Trophosome: Hydrocaulus monosiphonic, pinnate, bipinnate, or irregularly branched, attaining a height of about 10 cm.; pinnae alternate on regular forms; stem internodes with one to three hydrothecae, pinna internodes with one only. Hydrothecae tubular, distant, adnate more than one-half length, free portion divergent; margin of aperture with three teeth, the superior slightly recurved.



Figs 61-64.

Sertularella divaricata (Busk). Fig. 61: Portion of colony. Fig. 62: Gonotheca. *Sertularella pygmaea* Bale. Fig. 63: Portion of colony. Fig. 64: Gonotheca.

Gonosome: Gonothecae obovate, annulate, borne on the pinnae; aperture eccentrically placed, wide and tubuliform.

Dimensions:

Hydrocaulus internode, length	up to 2·00 mm.
Hydrotheca, length adnate	0·25-0·33 mm.
Hydrotheca, length free	0·08-0·13 mm.
Hydrotheca, diameter at aperture	0·15-0·17 mm.
Hydrotheca, diameter at base	0·12-0·15 mm.

Locality: Seven miles east of Cape Pillar, 100 fathoms (Briggs); Oyster Bay (May, 1949); Bicheno (May, 1949); Bass Strait (Bale).

Distribution: Recorded from Victoria; South Australia; Queensland; New Zealand, South America, Antarctica.

There is a considerable variation of form in the specimens in this collection. The internodes, particularly, are very variable in length, with the accompanying effect on both microscopic and macroscopic appearance. This variability is discussed at length by Bale (1914b, p. 20).

The specimens in this collection are mostly small, not exceeding 3 cm. in height; they were taken from storm-drifted seaweed.

Sertularella pygmaea Bale, 1881

(Figs 63, 64)

Sertularella pygmaea Bale, 1881.

Trophosome: Hydrocaulus simple, monosiphonic, attaining a height of about 1 cm., divided into internodes by twisted joints; each internode bears a hydrotheca distally. Hydrothecae tubular, divergent, smooth, adnate about half length; no floor to hydrotheca, but hydranth supported by a small ledge formed from the adcauline wall; margin of aperture with three teeth, one superior and two laterals.

Gonosome: Gonothecae borne on the lower part of the stem; large, transversely rugose, aperture on the end of a short tubular neck which arises within the most distal of the rugae; margin entire.

Dimensions:

Hydrocaulus internode, length	0·31-0·33 mm.
Hydrotheca, length	0·23-0·25 mm.
Hydrotheca, diameter	0·13-0·15 mm.
Gonotheca, length	0·75-0·80 mm.
Gonotheca, diameter	0·46 mm.

Locality: Oyster Bay (May, 1949); Bicheno (May, 1949).

Distribution: Recorded from Griffiths' Point (Goldstein); Portland (Maplestone); Queenscliff; New Zealand; Robe, S.A.

This species is not very abundant, only a few scattered colonies being found on storm-drifted kelp. The colonies were all under 1 cm. in height.

This species bears a marked resemblance in form to *Sertularella divaricata* Busk, but the simple unbranched habit, and the small size, provide a ready method of distinction.

Genus **Symplectoscyphus** Marktanner-Turneretscher, 1890

'Hydrocladia projecting in short hydrotheca-free processes which generally are attached to other hydrocladia or branches. Arrangement and shape of hydrothecae similar to that of *Sertularella*. Margin of aperture of hydrotheca toothed. One or more very delicate membranous valves, operculum-shaped, are present.

Gonothecae elongate, pyriform, annulate, a short tubuliform aperture at the distal end'. — Marktanner-Turneretscher.

Symplectoscyphus columnarius (Briggs, 1914)

(Fig. 65)

Sertularella columnaria Briggs, 1914.

Sympletoscyphus columnarius Totton, 1930.

Trophosome: Hydrocaulus polysiphonic, branched, attaining a height of about 7 cm.; stem divided into regular internodes by oblique joints which slope successively in opposite directions; each internode bears a hydrotheca or a hydrotheca and a branch; branches regular, monosiphonic, alternate, in one plane, arising below a hydrotheca, slightly constricted at origin, nodes becoming obscure. Hydrothecae borne at the distal end of internodes, adnate about half length, distant, tubular, smooth, curved outwards; margin of aperture with three teeth, one superior and two laterals; some tendency to regeneration, margin may be duplicated or triplicated.

Gonosome: Gonothecae ovate, three distinct rugae on distal half, proximal half smooth, aperture tubuliform and expanding.

Dimensions:

Hydrocaulus internode, length	1·04-1·16 mm.
Hydrocaulus internode, diameter	0·40-0·43 mm.
Branch internode, length	0·73-0·87 mm.
Branch internode, diameter	0·35-0·38 mm.
Hydrotheca, length adnate	0·64-0·70 mm.
Hydrotheca, length free	0·70-0·76 mm.
Hydrotheca, diameter at mouth	0·50-0·53 mm.
Gonotheca, length	3·19 mm.
Gonotheca, greatest diameter	1·30-1·68 mm.
Gonotheca, diameter of aperture	0·45 mm.

Locality: Seven miles east of Cape Pillar, 100 fathoms (Briggs); Off Maria Island, 65 fathoms (Briggs).

FIGS 65-67.

Symplectoscyphus columnarius (Briggs). Fig. 65: Portion of colony (after Briggs). *Thuiaria sinuosa* Bale. Fig. 66: Gonotheca (after Bale). Fig. 67: Portion of pinna (after Bale).

Distribution: Recorded from New Zealand (Bale); Off Three Kings Islands, New Zealand, 100 fathoms (Totton).

The measurements given above are taken from the descriptions by Briggs (1914, p. 293) and by Totton (1930, p. 180). There is no specimen in this collection.

Genus **Thuiaria** Fleming

'Zoophyte plant-like, stem branching, jointed, rooted by a filiform stolon; hydrothecae biserial, not in pairs, usually more or less immersed; gonothecae similar to those of *Sertularia*'. — Bale.

The adnate condition of the hydrotheca was originally taken to be the essential character of the genus *Thuiaria*, but this was shown by Allman to be quite inadequate. Allman went on to point out that a better distinguishing feature was the manner of jointing of the hydrocaulus, and stated that in the true Sertularians the jointing occurs between every two, or two pairs of hydrothecae. This, however, is definitely not a constant character in the Australian species.

The true distinction between *Thuiaria* and *Sertularia* is that in the former the hydrothecae are biserial, whereas in the latter they are in pairs; that is, in *Sertularia* there is always an even number of hydrothecae on an internode, while in *Thuiaria* odd or even numbers are equally likely to occur.

Thuiaria sinuosa Bale, 1888

(Figs 66, 67)

Thuiaria sinuosa Bale, 1888.

Trophosome: Hydrocaulus polysiphonic, pinnately branched, attaining a height of about 19 cm.; stem irregularly and indistinctly jointed; pinnae alternate, jointing also obscure; three hydrothecae between each two pinnae on the same side. Hydrothecae elongate, sub-conical, alternate on the stem, opposite to alternate on the pinnae; markedly biserial, adnate in lower half to the stem, and in the upper half to the hydrotheca above; a conspicuous triangular area below the base of each hydrotheca; aperture semi-circular, small, directed outwards.

Gonosome: Gonothecae borne on anterior of pinnae in rows; obovate, transversely rugose; aperture large, with elevated margin which possesses a few long internal spines.

Dimensions:

Stem, diameter of cladate tube	0·54 mm.
Pinna, length	up to 48·0 mm.
Pinna, diameter, including hydrotheca	0·47-0.50 mm.
Hydrotheca, length	0·61-0·64 mm.
Hydrotheca, greatest diameter	0·12-0·15 mm.
Gonangium, length	1·41-1·53 mm.
Gonangium, greatest diameter	0·68-0·75 mm.

Locality: Seven miles east of Cape Pillar, 100 fathoms (Briggs).

Distribution: Recorded from Station 54, within Jervis Bay, N.S.W., 10-11 fathoms (Ritchie); Port Molle, Queensland (Bale).

The measurements quoted above are taken from Briggs (1914, p. 294). There is no specimen in this collection.

Family PLUMULARIIDAE

'Hydrothecae sessile and unilateral. Zoophyte furnished with nematophores (minute calycles containing an extensile offshoot of the coenosarc, and frequently bearing thread-cells). Polypites with a single wreath of filiform tentacles around a conical proboscis; gonozooids always fixed'. — Hincks.

Genus **Plumularia** Lamarck, 1816 (in part)

'Zoophyte consisting of pinnate (or rarely undivided) shoots, often branched, jointed, rooted by a creeping stolon; hydrothecae generally more or less distant, margin not toothed; sarcothecae distributed along the hydrocaulus, not attached to the calycles; gonothecae never enclosed in corbulae nor protected by gonangial ramules'. — Bale.

The genus *Plumularia* includes species which possess a delicate hydrophyton, with the hydrothecae, and the pinnae, separated somewhat so as to give a slender and graceful appearance. Margins of the hydrothecae are always smooth. Sarcothecae are arranged on a definite plan, some regularly about the hydrothecae, others along the hydrocaulus; they are generally wine-glass shaped, narrow at the base ,and moveable; in some of the species those median in position are curved, fixed, with the adcauline wall cut away, and also with a stout attachment to the hydrocaulus.

Key to the Genus Plumularia

1.	Median sarcothecae fixed	2
	Median sarcothecae never fixed	5
2.	Pinnae internodes each with a hydrotheca set at about 45° to axis	3
	Pinnae with alternate long and short internodes, hydrothecae borne only on the former	4
3.	Hydrocaulus simple, monosiphonic	*P. buskii* Bale
	Hydrocaulus bipinnately branched, polysiphonic	*P. sulcata* Lamarck
4.	Hydrocaulus simple, monosiphonic; hydrothecae at 70° to pinna axis, wall markedly thickened	*P. filicaulis* Poeppig
	Hydrocaulus branched, polysiphonic; hydrotheca at 40° to pinna axis, borne proximally on internode	*P. campanula* Busk
5.	Hydrocaulus, polysiphonic	6
	Hydrocaulus monosiphonic	7
6.	Hydrocaulus branched, colony procumbent; hydrothecae adnate up to margin, aperture at 90° to pinna	*P. procumbens* Spencer
7.	Hydrocaulus simple; hydrothecae single, terminal on a pinna, abaxial wall convex	*P. obliqua* Saunders
	Hydrocaulus branched	8
8.	Hydrothecae single, terminal on a pinna, abaxial wall concave	*P. pulchella* Bale
	Pinnae with alternate long and short internodes, hydrothecae borne only on the former	9
9.	Hydrothecae adnate up to margin, aperture at 90° to pinna	*P. setacea* (Ellis)
	Hydrothecae at 40° to pinna axis, margin of aperture entire	*P. setaceoides* Bale

Plumularia obliqua (Saunders)

(Fig. 68)

Laomedea obliqua Saunders, in litt.
Campanularia sp. Lister, 1834.
Plumularia obliqua Hincks, 1861.

Trophosome: Hydrorhiza with marginal markings; hydrocaulus simple, monosiphonic, attaining a height of about 1·5 cm.; stem flexuous, slender; pinnae alternate, arising near distal end of internode, each supporting a single hydrotheca. Hydrothecae campanulate, rounded at base, laterally compressed, aperture at 90° to pinna axis, margin sinuous; from summit of pinna a vestigial intrathecal ridge

projects into the calycle. Sarcothecae canaliculate, bithalamic; one median below calycle, one lateral on each side on end of pinna, one axillary, and one near middle of stem internode. The two lateral sarcothecae above calycle have the upper chamber compressed.

Gonosome: Gonothecae large, ovate, truncate above.

Distribution: Recorded from Williamstown, Victoria; Tasmania; England.

I can find no record of the Tasmanian locality from which this specimen was recorded. There is no specimen in this collection and dimensions are not given.

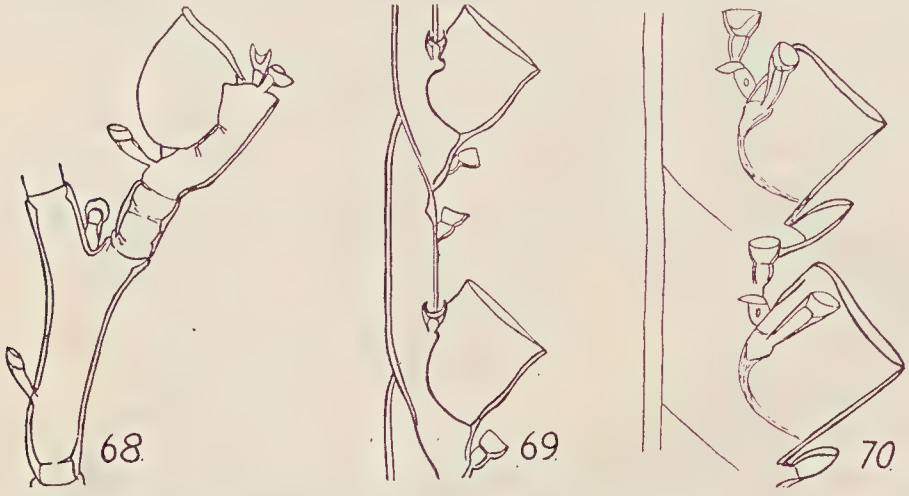
Plumularia campanula Busk, 1852

(Fig. 69)

Plumularia campanula Busk, 1852.
Plumularia indivisa Bale, 1881.
Plumularia laxa Allman, 1883.
Plumularia torresia von Lendenfeld, 1884.
Plumularia rubra von Lendenfeld, 1884.

Trophosome: Hydrocaulus branched, polysiphonic, erect, attaining a height of about 12 cm.; branches slender, pinnate, bearing both hydrothecae and pinnae; pinnae distant, alternate, arising from each or every second branch internode; pinna internodes long, with oblique joints, a hydrotheca borne on each, except the proximal of each pinna. Hydrothecae borne at the proximal end of internodes, large, campanulate, set at an angle of about 40° to pinna axis, margin entire, free at back. Sarcothecae canaliculate, bithalamic, median ones fixed with stout bases; one lateral, pedunculate, at each side of the hydrotheca, one median below, one between each two hydrothecae on the same internode as the lower, and one on the proximal internode of pinna.

Gonosome: Gonothecae ovate, tapering below, or short and broad; a sarcotheca on each side near peduncle.



FIGS 68-70.

Plumularia obliqua (Saunders). Fig. 68: Portion of colony (after Bale). *Plumularia campanula* Busk. Fig. 69: Portion of colony (after Bale). *Plumularia sulcata* Lamarck. Fig. 70: Portion of colony. (after Bale).

Locality: Twenty miles east of King Island, Bass Strait (Bale); Oyster Bay, 60 fathoms (Bale).

Distribution: Recorded from Holborn Island, 20 fathoms; Port Stephens (Haswell); Portland (Maplestone); Williamstown (Bale).

Dimensions are not given. There is no specimen in this collection.

The species is separated into two varieties, one being the large polysiphonic form as described above; the other, originally described as *Plumularia indivisa* (Bale, 1881, pp. 39, 36), consisting of short, slender shoots which bear hydrothecae only. Both varieties have been taken from Bass Strait.

Plumularia sulcata Lamarck, 1816

(Fig. 70)

Plumularia sulcata Lamarck, 1816.
Plumularia aglaophenoides Bale, 1884.

Trophosome: Hydrocaulus polysiphonic, bipinnately branched, attaining a height of 45 cm., or more; stem and branches thick, flexuous, giving rise to monosiphonic branchlets; branchlets alternate and pinnate, arising one from each flexure; from the branchlets arise pinnae which are alternate, approximate, with a hydrotheca on each internode, joints oblique becoming more or less obscure distally. Hydrothecae large, campanulate, set at an angle of 45° to pinna axis, margin with a broad sinuation adaxially. Sarcothecae canaliculate, bithalamic; one median, fixed, below hydrotheca to which it is almost adpressed, adaxial margin deeply cut away; two large, pedunculate, wine-glass shaped at the sides; two small, at the back of the hydrotheca with two larger just above; one or two on proximal internode of the pinna; generally a double series on proximal portion of the branchlet. Only the lateral sarcothecae are freely moveable.

Gonosome: Gonothecae urceolate, large, with an oblique, circular aperture, the margin of which is not thickened; a large internal operculum rests on an internal ridge just below the margin; base surrounded by several large sarcothecae (5-6).

Dimensions:

Gonosome, length	up to 1·6 mm.
Gonosome, maximum diameter	0·70-0·71 mm.

Locality: Off Wineglass Bay, Freycinet Peninsula, 80 fathoms (Briggs); Bass Strait, 40 fathoms (Bale).

Distribution: Recorded from Mers australes (Lamarck); Broughton Island, N.S.W., 25 fathoms (Bale); Station 48, off Wollongong, N.S.W., 55-56 fathoms (Ritchie); Fifty miles south of Cape Wiles, S.A., 75 fathoms (Bale).

The dimensions given above are from Briggs (1915, p. 306). There is no specimen in this collection.

Plumularia pulchella Bale, 1881

(Fig. 71)

Plumularia pulchella Bale, 1881.

Trophosome: Hydrocaulus branched, monosiphonic, attaining a height of about 2·5 cm., slender and flexuous; pinnae alternate, arising near distal end of internode, bearing a single hydrotheca, the distal part curving from beneath hydrotheca, widening upwards. Hydrothecae campanulate, with an entire, slightly everted margin which rises above distal end of pinna; aperture at 90° to pinna

axis. Sarcothecae canaliculate, bithalamic, with slender bases; one median below calycle, two laterals on end of pinna, two axillaries, and one near middle of stem internode.

Gonosome: Gonothecae very large, ovate, obliquely truncate, aperture with large internal teeth.

Dimensions:

Hydrocaulus internode, length	0·33-0·40 mm.
Hydrocaulus internode, diameter	0·04-0·05 mm.
Pedicel, length	0·10-0·11 mm.
Pedicel, diameter	0·026-0·03 mm.
Hydrotheca, depth	0·11-0·13 mm.
Hydrotheca, diameter at aperture	0·10-0·11 mm.

Locality: D'Entrecasteaux Channel; Rheban (May, 1949).

Distribution: Recorded from Williamstown, Victoria.

The specimens which form the basis of this description were found growing epizoically on a Bryozoan (D'Entrecasteaux Channel), and on *Macrocystis* (Rheban).

Bale (1884, p. 140) states that the hydrocaulus is unbranched; while this appears to be the usual condition, one specimen in this collection reaches a height of 2·5 cm., and is irregularly branched, the branches arising in or near the pinna axils. The hydrorhizae in all the specimens are filiform stolons and not in the form of a mat (Bale, 1884, p. 140). Also the constrictions of the pinnae behind the hydrothecae are obscure in these specimens. They are not visible in lateral view, and are seen only faintly in a frontal view. Gonothecae are absent.

Plumularia filicaulus Poeppig, 1876

(Fig. 72)

Plumularia filicaulus Poeppig, 1876.
Plumularia lucerna Mulder & Trebilcock, 1911.
Antennella filicaulus Bedot, 1917.

Trophosome: Hydrorhiza ribbon-like, edges indented in a castellate pattern. Hydrocaulus simple, monosiphonic, attaining a height of about 1 cm.; stem jointed, each internode bearing a pinna; pinnae alternate, consisting normally of successive long and short internodes, with hydrothecae borne only on the former. Hydrothecae cup-shaped, walls greatly thickened, the thickening on the adcauline side forming a short, broad intrathecal ridge; margin of aperture entire, sinuous. Median sarcothecae bithalamic, canaliculate, stout, fixed; one below the hydrotheca, and one on the short internode. Lateral sarcothecae wine-glass shaped, moveable, monothalamic (?), with slender bases, and very thin delicate walls; one on each side above hydrotheca, and somewhat protected by it. Cauline sarcothecae, resemble medians; one in the axil, and one on lower part of stem internode.

Gonosome: Gonothecae irregularly ovate, arising from the hydrorhiza and closely adnate by the flat underside to the supporting material; upper surface transversely rugose, convex; aperture sub-terminal, facing upwards.

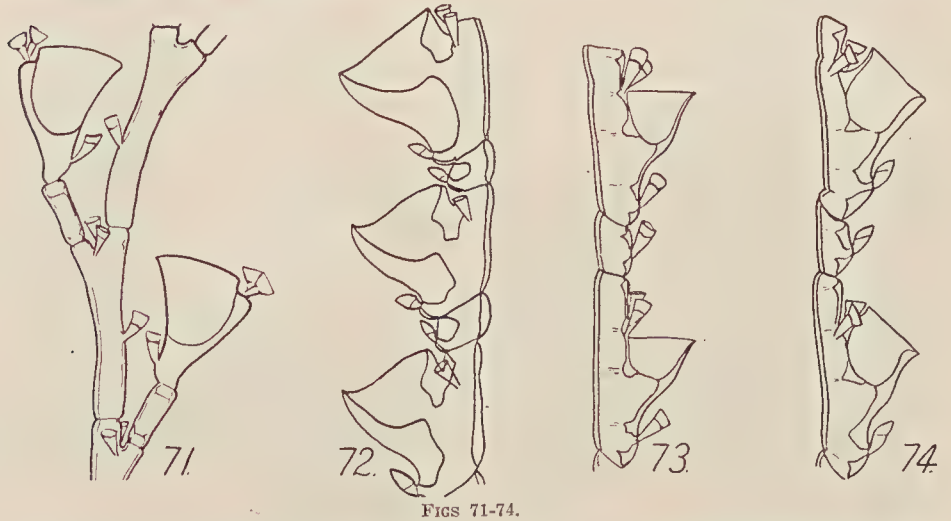
Dimensions:

Hydrocaulus internode, length	0·30-0·33 mm.
Hydrocaulus internode, diameter	0·07-0·10 mm.
Pinna internode (long), length	0·30-0·33 mm.
Pinna internode (short), length	0·10-0·12 mm.
Pinna internode, diameter	0·08-0·10 mm.
Hydrotheca, depth	0·12-0·13 mm.
Hydrotheca, breadth at aperture	0·25-0·28 mm.

Locality: Blackman's Bay, Derwent Estuary, 3-4 fathoms (July, 1949).

Distribution: Bay of Talcahuano, Chili (Poeppig); Portland (Maplestone); Point Lonsdale (Mulder & Trebilcock).

The specimen described above consists of a number of pinnate shoots. There are no simple shoots which, according to Mulder & Trebilcock (1916, p. 80), often arise from the same hydrorhiza as the pinnate shoots. The colony was growing on a divided *Macrocystis* lamina.



FIGS 71-74.

Plumularia pulchella Bale. Fig. 71: Portion of colony. *Plumularia filicaulus* Poeppig. Fig. 72: Portion of colony. *Plumularia setacea* (Ellis). Fig. 73: Portion of colony. *Plumularia setaceoides* Bale. Fig. 74: Portion of colony.

Plumularia setacea (Ellis, 1755)

(Fig. 73)

Corallina setacea Ellis, 1755.
Sertularia pinnata Linnaeus, 1758.
Sertularia setacea Pallas, 1766.
Aglaophenia setacea Lamouroux, 1816.
Aglaophenia gaymardi Lamouroux, 1824.
Plumularia setacea Lamarck, 1816.
Pennaria setacea Oken, 1815.
Plumularia multinoda Allman, 1886.
Plumularia tripartita von Lendenfeld, 1884.
Plumularia turgida Bale, 1888.
Plumularia palmeri Nutting, 1900.
Plumularia corrugata Nutting, 1900.

Trophosome: Hydrocaulus monosiphonic, sparingly branched, regularly jointed, attaining a height of about 5 cm.; pinnae alternate, arising at the distal end of stem internodes, with up to six hydrothecae. Alternate short and long internodes, former with a single sarcotheca only, the latter bearing both hydrothecae and sarcothecae. Hydrothecae campanulate, small, expanded upwards, back adnate up to the margin which is entire; aperture at 90° to pinna axis, or nearly so; borne near the middle of internodes, hydranths small, completely retractile, with a ring of 18 tentacles. Sarcothecae wine-glass shaped, bithalamic, canaliculate, with slender bases; one median below the hydrotheca, one lateral on each side above, one median on short internode, one or two in pinna axil, and one near proximal end of stem internode.

Gonosome: Gonothecae differ in the sexes; female smooth, ampullate, with a tubular neck and large orifice; male more slender and elongate, with a very narrow neck and a small terminal aperture.

Dimensions:

Hydrocaulus internode, length	0·30-0·33 mm.
Hydrocaulus internode, diameter	0·11-0·13 mm.
Pinna internode (long), length	0·30-0·33 mm.
Pinna internode (short), length	0·10-0·13 mm.
Pinna internode, diameter	0·05-0·07 mm.
Hydrotheca, depth	0·08-0·10 mm.
Hydrotheca, diameter at aperture	0·10-0·12 mm.
Gonotheca (male), length	up to 0·90 mm.
diameter	up to 0·20 mm.
Gonotheca (female), length	up to 0·90 mm.
diameter	up to 0·33 mm.

Locality: South Arm, Derwent Estuary (April, 1947); Eaglehawk Neck (February, 1948); Oyster Bay (May, 1949).

Distribution: Recorded from S.E. Australia; New Zealand; Europe.

The living specimen has a very delicate and graceful appearance. Being quite colourless and transparent, it is often very difficult to see.

The present specimens were found growing on *Macrocystis* and other algae in shallow water.

There are two forms represented in this collection, one corresponding to the type as described by Hincks (1868, p. 296), the other to that originally described by Bale (1888, p. 779) as *Plumularia turgida*. The latter is more often branched and has two sarcothecae at the base of the pinna, one in front of the axil, and one behind. This type has been taken only from Eaglehawk Neck, where it occurs in association with *Halecium flexile* Allman.

Plumularia setaceoides Bale, 1881

(Fig. 74)

Plumularia setaceoides Bale, 1881.

Trophosome: Hydrorhiza ribbon-like, with undulated edges. Hydrocaulus monosiphonic, rarely branched, attaining a height of about 7-8 cm., divided into internodes by oblique joints; pinnae alternate, distant, borne near the distal ends of internodes, consisting of alternate long and short internodes, with hydrothecae borne only on the former. Hydrothecae at an angle of about 40° to pinna axis, campanulate; aperture round, with an entire margin. Sarcothecae wine-glass

shaped, canaliculate, bithalamic, base slender, cup shallow; median sarcothecae (on both long and short internodes) have the margin cut away on the ad-axial side; sarcothecae one below each hydrotheca, one lateral on each side above, one median on the short internode, one in the pinna axil, and one near the proximal end of the stem internode.

Gonosome: Gonothecae large, obliquately truncate above the broadest part, transversely rugose; borne at the bases of pinnae, often in two rows on the stem.

Dimensions:

Hydrocaulus internode, length	0·30-0·33 mm.
Hydrocaulus internode, diameter	0·12-0·13 mm.
Pinna internode (long), length	0·30-0·35 mm.
Pinna internode (short), length	0·08-0·10 mm.
Pinna internode, diameter	0·05-0·08 mm.
Hydrotheca, depth	0·12-0·13 mm.
Hydrotheca, diameter at aperture	0·13-0·15 mm.

Locality: South Arm, Derwent Estuary (April, 1948); Nubeena, Tasman Peninsula (April, 1949); Bicheno (May, 1949).

Distribution: Recorded from Victoria; New South Wales.

In the present specimens there is a considerable variation in the thickening of the hydrothecal walls. The specimen from Nubeena has markedly thickened walls, as opposed to the condition found in all the remaining specimens. Apparently, however, this is not sufficient grounds for the formation of a new variety, for Bale (1888, p. 781) also records the same characteristic.

An interesting feature is that the specimen from Nubeena was growing epizoically on a pleopod of *Jasus lalandii* (Tasmanian Marine Crayfish). The specimens from South Arm were taken from algae below low-tide level, and those from Bicheno, were found on storm-drifted seaweed.

Plumularia buskii Bale, 1884

(Fig. 75)

Plumularia buskii Bale, 1884.
Plumularia nuttingi Billard, 1911.
Plumularia buski Billard, 1913.

Trophosome: Hydrocaulus simple, monosiphonic, attaining a height of about 5-6 cm., bearing hydrothecae as well as pinnae; pinnae arise towards the front, and are approximate, alternate, joints oblique, a hydrotheca on each internode except the proximal. Hydrothecae large, set at an angle of about 45° to the pinna axis, margin entire and free at the back. Sarcothecae canaliculate, bithalamic, the median ones fixed with stout bases; one, pedunculate, on each side above the hydrotheca, one median sub-calycine, fixed, curved, almost appressed to the hydrotheca, one median supra-calycine behind hydrotheca, one on distal part of internode near joint, one on proximal internode of pinna, and two abreast on the distal end of stem internode.

Gonosome: Gonothecae (female) large, borne on the stem, 'having a turgid dorsum and a more flattened ventral surface', Bale (1914, p. 28); two series of 5-6 large, moveable, irregularly arranged sarcothecae on the dorsal surface, also a single one near apex in central line.

The male gonothecae are small, borne on the pinnae, ovate, with a pair of sarcothecae near peduncle.

Dimensions:

Hydrocaulus internode, length	0·70-0·73 mm.
Hydrocaulus internode, diameter	0·29-0·33 mm.
Pinna, length	up to 9·00 mm.
Pinna (hydrothecate) internode, length	0·57-0·61 mm.
Hydrotheca, depth	0·29-0·31 mm.
Hydrotheca, diameter at aperture	0·26-0·28 mm.

Locality: D'Entrecasteaux Channel, 2-11 fathoms (Briggs).

Distribution: Recorded from Griffiths' Point, Victoria (Bale); Laysan Island, Hawaiian Archipelago (Hartlaub); Gulf of Manaar (Thornely); Christmas Island (Ritchie); Great Australian Bight (Bale).

The measurements given above are taken from Briggs (1915, p. 304). There is no specimen in this collection.

Plumularia procumbens Spencer, 1891

(Figs 76, 77)

Plumularia procumbens Spencer, 1891.
Plumularia setaceaformis Mulder & Trebilcock, 1915.

Trophosome: Hydrocaulus branched, polysiphonic, attaining a height of about 15 cm., the whole colony procumbent; branching is in one plane, with pinnae arising from both stem and branches; pinnae alternate, composed of successive long and short internodes, former bearing hydrothecae and sarcothecae, the latter bearing sarcothecae only, and then not constantly. Hydrothecae small, adnate up to margin which is smooth; aperture at about 90° to pinna axis. Sarcothecae large, bithalamic, canaliculate; one median below the hydrotheca, one lateral on each side above, two in the pinna axil, and numerous others scattered over the branches and stem.

Figs 75-78.

Plumularia buskii Bale. Fig. 75: Portion of colony (after Bale). *Plumularia procumbens* Spencer. Fig. 76: Portion of colony (after Spencer). Fig. 77: Gonotheca (after Spencer). *Nemertesia celiata* Bale. Fig. 78: Portion of colony (after Bale).

Gonosome: Gonothecae (male) ovate, borne on a short stalk, in a position axillary to a pinna; aperture large, terminal. One sporosac.

Dimensions:

Hydrocaulus (pinnate) internode, length	0·61-0·64 mm.
Hydrocaulus (pinnate) internode, diameter	0·12-0·14 mm.
Pinna internode (long), length	0·20-0·31 mm.
Pinna internode (short), length	0·10-0·12 mm.
Pinna internode, diameter	0·03-0·04 mm.
Hydrotheca, depth	0·05-0·06 mm.
Hydrotheca, diameter at aperture	0·08 mm.
Supra-calycine sarcotheca, length	0·07-0·08 mm.

Locality: Off Wineglass Bay, Freycinet Peninsula, 80 fathoms (Briggs).

Distribution: Recorded from Port Phillip, Victoria (Spencer); Great Australian Bight, 40-100 fathoms (Bale).

The measurements quoted above are those given by Briggs (1915, p. 305). There is no specimen in this collection.

Genus **Nemertesia** Lamouroux, 1812

'Zoophyte plant-like; stems simple or branching. jointed, clothed with verticillate branchlets, and rooted by a mass of fibres; hydrothecae cup-shaped; nematophores bithalamic, distributed along the stem (and branchlets); gonothecae axillary, unilateral'. — Hincks.

Nemertesia ciliata Bale, 1914

(Fig. 78)

Nemertesia ciliata Bale, 1914c.

Trophosome: Hydrocaulus in one plane, polysiphonic, profusely branched, attaining a height of about 30 cm.; main branches bear branchlets which are monosiphonic, biserial, opposite to alternate, divided into internodes, each of which, except the first, bears one to eight whorls of pinnae; each whorl consists of three to four pinnae which are divided into alternate long and short internodes, the former hydrothecate, the latter bearing sarcothecae only. Hydrothecae very small, cup-shaped, adnate to the margin which is smooth. Sarcothecae bithalamic, canaliculate, large, moveable; one median in front of hydrotheca, two laterals above, one on short internodes, and two in each pinna axil.

Gonosome: Gonothecae small, delicate, campanulate, with very thin walls; gonothecae expand from base to apex; aperture wide, open, transverse; no operculum.

Dimensions:

Pinna internode (thecate), length	0·26-0·29 mm.
Pinna internode (intermediate), length	0·15-0·17 mm.
Pinna internode, diameter	0·05-0·06 mm.
Hydrotheca, depth	0·05 mm.
Hydrotheca, diameter at aperture	0·05-0·06 mm.
Gonotheca, length	0·037-0·044 mm.

Locality: Thirty-five miles south-east of Bruni Island, 150-230 fathoms (Bale); Oyster Bay, 60 fathoms (Bale); Off Wineglass Bay, Freycinet Peninsula, 80 fathoms (Briggs).

Measurements quoted above are from Briggs (1915, p. 307) and Bale (1915, p. 300), there being no specimen in this collection.

Nemertesia ciliata Bale, var. cruciata Bale, 1915

Trophosome: Hydrocaulus similar to that of *Nemertesia ciliata* Bale, except that the pinnae are usually paired, each pair alternating with those above and below. Bale (1915, p. 300) states that: 'Excepting on the proximal portions of the branches the arrangement of the hydrocladia in alternate pairs is very general, though occasionally a branch bears them in sets of three, in which case there is often more or less irregularity among them. The branches seem to begin, more frequently than in the type, with two or three internodes devoid of hydrocladia, and, as in the type, the first few hydrocladia on a branch are irregular in position. A frequent arrangement is for two hydrocladia, nearly opposite, to begin the series, followed by three, all different heights, the rest being in alternate pairs; many other variations, however, occur. No gonangia were seen'.

Locality: Off South Cape, 75 fathoms (Bale); Twenty-five miles north-east of Babel Island, Bass Strait, 70-100 fathoms (Bale).

Genus **Halicornopsis** Bale, 1881

'Hydrocaulus pinnate; hydrothecae with a fixed anterior sarcotheca, lateral sarcothecae absent; median sarcostyles present, naked or protected by a rudimentary sarcotheca. Gonothecae not borne in corbulae, nor on modified pinnae'. — Bale.

The absence of lateral sarcothecae is a characteristic which immediately separates this genus, together with *Kirchenpaueria*, from the other *Aglaophenia*-type members of the Plumulariidae.

The median sarcostyle, the presence of which remained unnoticed for a long while, increases the affinity of the relationship between this genus and *Kirchenpaueria*.

Halicornopsis elegans (Lamarck, 1816)

(Fig. 79)

Plumularia elegans Lamarck, 1816.
Aglaophenia elegans Lamouroux, 1816.
Aglaophenia avicularis Kirchenpauer, 1872.
Halicornopsis avicularis Bale, 1881.
Azygoplon rostratum Allman, 1883.
Halicornopsis elegans Billard, 1907b.

Trophosome: Hydrocaulus branched, monosiphonic, becoming polysiphonic in the older parts, attaining a height of about 15 cm.; branching irregular; pinnae close, alternate, one or two on an internode. Hydrothecae set at an angle of about 45° to pinna axis; shallow, with two lateral teeth on margin, and a large anterior rostrum. Rostrum hollow, the inner side produced downwards to form an intrathecal ridge within the hydrotheca. Median sarcothecae short, scoop-shaped, open on the inner side, situate on the front of the hydrotheca opposite the base of the rostrum; cauline sarcothecae small, one on the branch above origin of pinna,

one on base of pinna, and one axillary. A median sarcostyle is present, situated between the pinna and the back of the hydrotheca, naked, or protected by a rudimentary sarcotheca in the form of a delicate flap of perisarc; sarcopore a simple aperture communicating with the interior of the pinna.

Gonosome: Gonothecae irregularly ovate, thick-walled, borne at the bases of the pinnae; no visible orifice or operculum.

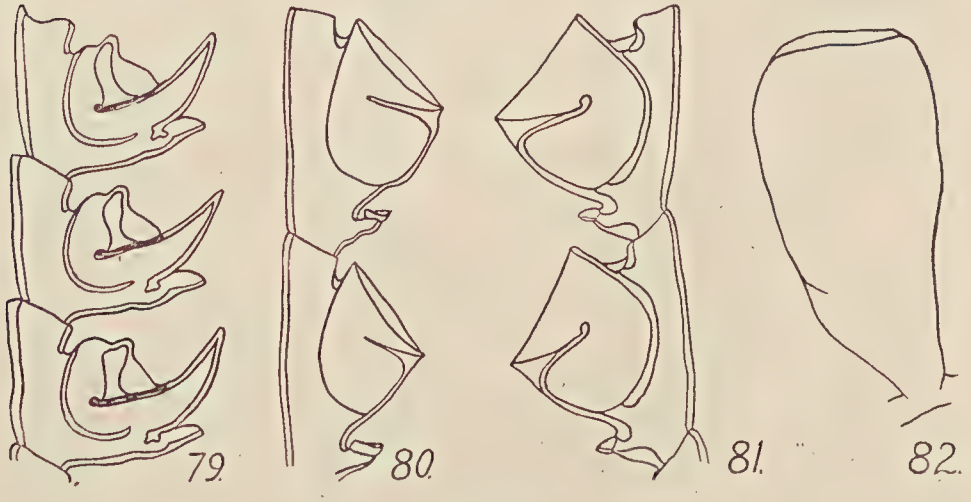
Dimensions:

Hydrocaulus internode (single pinna), length	0·61-0·73 mm.
Hydrocaulus internode (double pinna), length	0·97-1·38 mm.
Hydrocaulus internode (pinnate), diameter	0·28-0·36 mm.
Pinna internode, length	0·42-0·45 mm.
Pinna internode, diameter	0·12-0·17 mm.
Hydrotheca, depth	0·29-0·31 mm.
Hydrotheca, diameter at aperture (lateral aspect)	0·26-0·28 mm.
Hydrotheca, diameter at aperture (frontal aspect)	0·36-0·40 mm.
Gonotheca, length	1·31 mm.
Gonotheca, greatest diameter	0·73-0·80 mm.

Locality: Off South Cape, 75 fathoms (Bale); D'Entrecasteaux Channel, 2-11 fathoms (Briggs); Hobart, Derwent Estuary; Seven miles east of Cape Pillar, 100 fathoms (Briggs); Wineglass Bay, 11 fathoms (Briggs); Bass Strait (Kirchenpauer); Bass Strait (Bale).

Distribution: Recorded from Indian Ocean (Lamouroux); Great Australian Bight, 40-100 fathoms (Bale); Victoria; New South Wales.

The measurements quoted above are those given by Briggs (1915, p. 309). There is no specimen in this collection.



FIGS 79-82.

Halicornopsis elegans (Lamarck). Fig. 79: Portion of pinna. *Kirchenpaueria producta* (Bale). Fig. 80: Portion of pinna (after Bale). *Kirchenpaueria mirabilis* (Allman). Fig. 81: Portion of pinna. Fig. 82: Gonotheca.

Genus **Kirchenpaueria** Jickeli, 1883

'Hydrocaulus pinnate, hydrocladia furnished with median sarcothecae, but none at the sides of the hydrothecae; median sarcostyles present which are not provided with sarcothecae, but communicate with the interior of the hydrocladia by simple apertures in the perisarc.

Gonangia without phylactocarps of any kind, sometimes adnate by one side to a foreign substance'. — Bale.

Kirchenpaueria mirabilis (Allman, 1883)

(Fig. 81, 82)

Diplocheilus mirabilis Allman, 1883.
Kirchenpaueria mirabilis Bale, 1894.
Plumularia mirabilis Billard, 1910.
Diplocheilus allmani Torrey, 1904.

Trophosome: Hydrocaulus monosiphonic or slightly fascicled, sparingly branched, attaining a height of about 8 cm.; stem internodes long; pinnae alternate, arising near the distal end of stem internode. joints oblique. Hydrothecae, one on each pinna internode; proximal portion nearly parallel with pinna, distal portion curved away; aperture circular, margin free and everted; anterior wall of hydrotheca inflected immediately below margin forming a deep intrathecal ridge which extends more than half way across the cell, external sinus filled with perisarc. A median sarcotheca below each hydrotheca, fixed erect, aperture facing the hydrotheca, terminal chamber wide, shallow, with adaxial wall deeply cut away. No lateral sarcothecae, but a median sarcostyle between back of hydrotheca and the pinna; sarcostyle a simple aperture partially protected by a web of perisarc connecting hydrotheca and pinna. A single sarcotheca at the base of each pinna, and one or two others near; one, conical, in the axil.

Gonosome: Gonothecae borne, one on an internode, on the lower part of the stem; large, free, with rounded summit, and irregular, wide, transverse undulations; no distinct marginal ring or operculum. Sporosacs two.

Dimensions:

Hydrocaulus internode, length	0·49-0·75 mm.
Hydrocaulus internode, diameter	0·16-0·25 mm.
Pinna internode, length	0·50-0·61 mm.
Hydrotheca, depth	0·28-0·33 mm.
Hydrotheca, diameter at aperture	0·30-0·33 mm.
Gonotheca, length	up to 1·60 mm.
Gonotheca, maximum breadth	0·85 mm.

Locality: D'Entrecasteaux Channel, 2-11 fathoms (Briggs); South Arm, Derwent Estuary (April, 1949); Storm Bay (Briggs); Station 162, off Moncoeur Island, Bass Strait (Allman).

Distribution: Recorded from Port Phillip and Griffiths' Point, Victoria (Bale); Scottburgh, Natal (Warren); Station 44, off Coogee, N.S.W., 49-50 fathoms (Ritchie); Misaki, Japan (Stechow); Pt. Loma, California, U.S.A. (Torrey).

A number of colonies were found on the hold-fast of *Macrocystis* which had been washed up on a beach at South Arm. Some of the colonies bore the characteristic gonothecae which have a reddish-brown colour, the remainder of the colony being colourless. Measurements differ somewhat from those given by Briggs (1915, p. 308), the stem internodes never attaining the minimum length quoted (0·87 mm.).

Kirchenpaueria producta (Bale, 1881)

(Fig. 80)

Plumularia producta Bale, 1881.
Azygoplon productum Bale, 1888.
Kirchenpaueria producta Bale, 1894.
Halicornaria producta Torrey, 1902.
Not *Diplocheilus allmani* Torrey, 1904.

Trophosome: Hydrocaulus monosiphonic, unbranched, attaining a height of about 1 cm.; pinnae alternate, either one or two borne on each internode. Hydrothecae borne one on each pinna internode, proximal portion nearly parallel to the pinna, the distal portion curving upwards; aperture with an entire margin; anterior wall of hydrotheca inflected below the margin so as to form an intrathecal ridge which extends more than half way across the cell. A median sarcotheca below each hydrotheca, fixed, erect, the distal chamber shallow or saucer-shaped, with the adaxial wall cut away. A single median sarcostyle in the angle between the hydrotheca and the pinna, protected by a delicate extension of perisarc between the hydrotheca and the pinna. Cauline sarcothecae, two at the base of the pinna, one of which is axillary and larger than the other, both just conical projections.

Gonosome: Gonothecae large, irregularly ovate, attached to the hydrorhiza by the flat ventral surface; dorsal surface is convex, with indistinct transverse undulations.

Locality: Bass Strait (Bale).

Distribution: Recorded from Coogee, N.S.W.; Port Jackson, N.S.W. (Bale); Queenscliff; Williamstown; Portland.

No dimensions are given. There is no specimen in this collection.

Genus **Halicornaria** Busk, 1852

'Shoots plumose, pinnate, often branched, rooted by a filiform stolon; hydrothecae generally toothed or lobed at the margin; a median anterior and two lateral sarcothecae connected with each hydrotheca, no others along the polypiferous ramules; gonothecae naked, on the main stem or the unaltered pinnae'. Bale.

A number of the species which have been placed in this genus have lacked the gonosome, so that the assignation must be provisional. However, such is the character of the remainder of the polypidom that there is little doubt that, in most cases, there will be agreement in the structure of the gonosome.

Halicornaria longirostris (Kirchenpauer, 1872)

(Fig. 83)

Aglaophenia longirostris Kirchenpauer, 1872.
Aglaophenia thompsoni Bale, 1881.
Halicornaria longirostris Bale, 1884.

Trophosome: Hydrocaulus monosiphonic, branched, attaining a height of about 9 cm.; branches in one plane; pinnae close, one or two on an internode, alternate to sub-alternate. Hydrothecae cup-shaped, set at an angle of about 45° to pinna axis, one on each pinna internode; margin of aperture with an incurved, spine-like tooth in front, a broad, shallow, rounded lobe behind, and three teeth on each side; thecate internodes not constricted. Median sarcotheca more than double the length of the hydrotheca, to which it is adnate as far as the margin; upper part tubular,

curved and produced forwards parallel to the pinna; lateral and terminal orifices distinct. Lateral sarcothecae small, oval, adnate to pinna; orifice tubular, lateral and terminal apertures may be confluent. Cauline sarcothecae similar to the laterals, one behind each pinna, and two on the front of stem internode.

Gonosome: Gonothecae small, delicate, truncate, borne at the bases of the pinnae.

Dimensions:

Hydrocaulus internode, length	0·55-0·58 mm.
Hydrocaulus internode, diameter	0·30-0·33 mm.
Pinna internode, length	0·23-0·27 mm.
Pinna internode, diameter	0·12-0·14 mm.
Hydrotheca, depth	0·18-0·21 mm.
Hydrotheca, breadth	0·17-0·19 mm.
Gonotheca, length	up to 0·60 mm.
Gonotheca, breadth	up to 0·40 mm.

Locality: Blackman's Bay, Derwent Estuary (March, 1938); Taroona, Derwent Estuary (August, 1949); Storm Bay (Briggs); Bicheno (May, 1949).

Distribution: Recorded from Victoria; South Australia; New South Wales.

The specimens in this collection consist of simple, pinnate colonies, none exceeding 7 cm. in height. The gonothecae, present on the specimen from Blackman's Bay, are borne in a single row up the stem, for the greater part of the length.

Halicornaria comes (Bale, 1914)

(Fig. 84)

Halicornaria intermedia Bale, 1914b.
Halicornaria furcata var. *intermedia* Bale, 1914b.
Halicornaria comes Briggs, 1939.

Trophosome: Hydrocaulus branched, monosiphonic, attaining a height of about 30 cm.; branching in one plane, dichotomous; pinnae arise two on an internode, alternate or sub-alternate; internodes with oblique joints. Hydrothecae set at an angle of about 60° to the pinna axis, facing towards the front; base wider than aperture; an intrathecal ridge runs obliquely from the abaxial wall to about the centre of the cell; margin of aperture entire or with an indistinct median tooth in front, a broad rounded lobe behind, and three teeth on each side, the centre one everted, the others degenerate; aperture between hydrothecae and pinna with minute marginal denticles; internode non-septate. Median sarcotheca adnate up to hydrotheca margin, the free part short, slender, with lateral and terminal orifices distinct. Lateral sarcothecae adnate, saccate, the two terminal orifices, one of which faces forwards, the other upwards, often more or less confluent with the large lateral aperture. Cauline sarcothecae similar to the laterals, two at the base of each pinna, and one at the back of axil.

Dimensions:

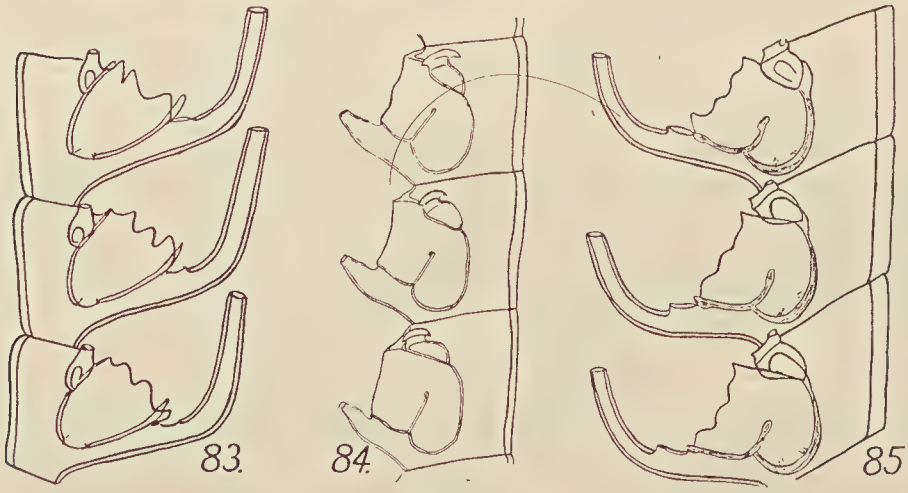
Hydroclade, length	up to 18·00 mm.
Hydroclade internode, length	0·39-0·42 mm.
Hydroclade internode, diameter	0·26-0·31 mm.
Hydrotheca, depth	0·29-0·31 mm.
Hydrotheca, breadth	0·18-020 mm.
Hydrotheca, length of free portion of mesial sarcotheca	0·09-0.21 mm.

Locality: Seven miles east of Cape Pillar, 100 fathoms (Briggs); Off Maria Island, 65 fathoms (Briggs); Oyster Bay, 20 fathoms (Bale); Off Wineglass Bay, 80 fathoms (Briggs); Bass Strait (Bale); Thirty-six miles S. 58° W. of Cape Wickham Lighthouse, 72 fathoms (Bale); Off Green Cape, 470 fathoms (Bale).

The lengths of the free parts of the median sarcothecae show a marked variation, presenting, in general, a series which decreases from the proximal portion of the pinna to the end.

This species has, so far, only been taken in Tasmanian waters in association with *Aglaophenia tasmanica* Bale, on which it occurs as an epizöon.

The measurements quoted above are those given by Briggs (1915, p. 311). There is no specimen in this collection.



Figs 83-85.

Halicornaria longirostris (Kirchenpauer). Fig. 83: Portion of pinna. *Halicornaria comes* (Bale). Fig. 84: Portion of pinna (after Bale). *Halcornaria superba* (Bale). Fig. 85: Portion of pinna (after Bale).

Halicornaria superba (Bale, 1881)

(Fig. 85)

Aglaophenia superba Bale, 1881.
Halicornaria superba Bale, 1884.

Trophosome: Hydrocaulus monosiphonic, sparingly branched, attaining a height of about 20cm.; pinnae two on each internode, close, alternate to sub-alternate. Hydrothecae set an an angle of about 60° to pinna axis, cup-shaped, with distal part somewhat bent upwards from pinna; a distinct intrathecal ridge projects from the middle of the abaxial wall to near the centre of the hydrotheca; margin of aperture entire, with a rudimentary anterior tooth in front, a free, broad, rounded lobe behind, and three everted teeth on each side, the most posterior often being reduced or absent; thecate internodes not constricted. Mesial sarcotheca about double the length of the hydrotheca to which it is adnate as far as the margin, distal portion curved and produced forwards nearly parallel to the pinna; lateral and terminal apertures separate. Lateral sarcothecae saccate, adnate, two

circular, sub-tubular apertures, one directed forwards, the other upwards; both apertures often confluent with the large lateral aperture. Cauline sarcothecae resemble the laterals, one behind pinna, and two on the front of the stem.

Gonosome: Unknown.

Dimensions:

Hydrocaulus internode, length	0·56-0·77 mm.
Hydrocaulus internode, diameter	up to 0·87 mm.
Pinna internode, length	0·28-0·31 mm.
Pinna internode, diameter	0·24-0·26 mm.
Hydrotheca, depth	0·24-0·26 mm.
Hydrotheca, breadth	0·17-0·19 mm.

Locality: Storm Bay (Briggs); Twenty miles east of King Island, Bass Strait (Bale).

Distribution: Recorded from Griffiths' Point (Goldstein); Queenscliff, Victoria; Port Phillip Heads, Victoria; Forty miles west of Kingston, S.A., 30 fathoms (Bale); Dongarra Beach, W.A. (Bale).

The measurements quoted above are those given by Briggs (1915, p. 312). There is no specimen in this collection.

Genus **Aglaophenia** Lamouroux, 1812 (in part)

'Shoots plumose, pinnate, often branched, rooted by a filiform stolon; hydrothecae generally toothed or lobed at the margin; a median anterior and two lateral sarcothecae connected with each hydrotheca, no others along the polypiferous ramules; gonothecae enclosed in corbulae or borne on specially modified pinnae'. — Bale.

The members of this genus have a characteristic feather-like appearance contrasting with the more delicate structure of the species of *Plumularia*.

Macroscopically this genus closely resembles *Halicornaria*, the character and position of the reproductive organs being the main distinguishing features. Here the gonothecae are never borne naked on the stem, but always on a pinna which is modified in some way to form a protective structure.

The mesial sarcotheca shows a range from forms with distinct lateral and terminal apertures, to forms in which these apertures are confluent. There are no sarcothecae on the pinnae other than those associated with the hydrothecae, but there are usually two or more on the stem at the base of each pinna. Sarcothecae are fixed, tubular or saccate, but not wine-glass shaped, attached partly to the hydrotheca and partly to the pinna.

The Australian members of the genus may be separated into several well-defined groups, the separation depending on characteristics of the trophosome and gonosome. This is discussed at length by Bale (1884, pp. 147-153).

Key to the Genus Aglaophenia

1.	Hydrocaulus simple, monosiphonic	2
	Hydrocaulus branched, polysiphonic	3
2.	Hydrothecae elongate; margin of aperture with an everted angular lobe on each side	*A. plumosa* Bale
	Hydrothecae urn-shaped; margin with four teeth on each side, the second from front more or less bilobed	*A. parvula* Bale
3.	Mesial sarcothecae extending beyond hydrotheca rim; hydrotheca margin with four teeth on each side	5
	Mesial sarcothecae not extending beyond hydrotheca rim	4
4.	Hydrothecal margin having one small triangular tooth on each side	*A. tasmanica* Bale
	Hydrothecal margin having three teeth on each side	*A. armata* Bale
	Hydrothecal margin having four teeth on each side	*A. tenuissima* Bale
5.	Hydrothecae with marginal anterior median tooth long, incurved	*A. divaricata* (Busk)
	Hydrothecae with marginal anterior median tooth everted	*A. decumbens* Bale

Aglaophenia tenuissima Bale, 1914

(Fig. 86)

Aglaophenia tenuissima Bale, 1914c.

Trophosome: Hydrocaulus very slender, flexuous, polysiphonic, branching, attaining a height of about 40 cm.; branches arise at flexures, monosiphonic, alternate, delicate, bearing only sarcothecae on proximal portions, jointing obscure; pinnae short, alternate, one on an internode. Hydrothecae almost cylindrical, nearly parallel with pinna axis, a minute intrathecal ridge on adcauline side near the base; aperture oblique, margin furnished with a short, pointed, anterior tooth, and on each side four equal triangular teeth which are similar to the anterior tooth but shorter; back adnate, Septal ridges opposite base of lateral sarcothecae and intrathecal ridge, with often a third between. Mesial sarcotheca less than one half length of hydrotheca, adnate, free portion very short, single terminal aperture. Lateral sarcothecae small, adnate up to margin, beyond which there is only a small projection; single terminal aperture. Cauline sarcothecae resemble the laterals, but are larger; one in axil of pinna, and one lower down behind axil.

Gonosome: Pinna replaced by a gonangial branch, the first three or four internodes bearing modified hydrothecae. Female: Corbula consisting of about fifteen pairs of pinnules; pinnules narrow proximally, but widened distally into broad leaflets, which meet to form the closed corbula. From base of each pinnule, on distal side, projects forwards a lateral spur which supports, proximally, a modified hydrotheca with its attendant lateral sarcothecae, and is continued distally into a leaf-like process, which may be very large, and armed with a few sarcothecae. The distal edges of the pinnules are free, wing-like, directed outwards, and continued above corbula, the edges with infrequent, scattered sarcothecae; often one or two free pinnules at distal or both ends of corbula.

Dimensions:

Hydrocaulus internode (pinnate), length	0·54-0·78 mm.
Hydrocaulus internode (pinnate), diameter	0·14-0·17 mm.
Pinna internode, length	0·45-0·47 mm.
Pinna internode, diameter	0·07-0·08 mm.
Hydrotheca, depth	0·33-0·35 mm.
Hydrotheca, breadth at mouth	0·18-0·19 mm.

Locality: Off Wineglass Bay, Freycinet Peninsula, 80 fathoms (Briggs).

Distribution: Previously recorded only from the Great Australian Bight, Long. 126° 45¼′ E., 190-320 fathoms; Long. 130° 40′ E., 160 fathoms (Bale).

The measurements recorded here are those given by Briggs (1915, p. 318). There is no specimen in this collection.

Aglaophenia plumosa Bale, 1881

(Fig. 87)

Aglaophenia plumosa Bale, 1881.

Trophosome: Hydrocaulus monosiphonic, unbranched, attaining a height of about 3-4 cm.; pinnae close, alternate, arising one on each internode, both series borne towards the front of stem. Hydrothecae elongate, nearly parallel with pinna axis, two small intrathecal ridges, one short, stout, on abcauline side at base of median anterior tooth, the other rudimentary, on adcauline side near base of hydrotheca; aperture at about 45° to pinna axis; margin of aperture with a long pointed, slightly incurved tooth in front, sides each forming an everted angular lobe, cut-away down to pinna. Septal ridges two, one at base of lateral sarcotheca, running obliquely forward, the other transverse, opposite the adcauline intrathecal ridge; occasionally a third between. Mesial sarcotheca long, divergent, with distinct terminal and lateral apertures, also an opening leading into the hydrotheca. Lateral sarcothecae tubular, adnate to the hydrotheca as far as the margin, with a free part above directed forwards and outwards, distinct lateral and terminal apertures. Cauline sarcothecae two on stem at base of pinna, apertures confluent.

Gonosome: Normal pinna replaced by a gonangial pinna which bears 15-20 pairs of alternate pinnules; each pinnule furnished with two series of tubular sarcothecae; sarcothecae opposite or sub-alternate, the two proximal ones on the distal edge of pinnule without corresponding ones on the proximal edge; the two series of pinnules are arched, meeting at the top and forming an open corbula; a single hydrotheca on pinna below corbula.

Dimensions:

Hydrocaulus internode (pinnate), length	0·25-0·32 mm.
Hydrocaulus internode (pinnate), diameter	0·17-0·23 mm.
Pinna internode, length	0·29-0·33 mm.
Pinna internode, diameter	0·10-0·13 mm.
Hydrotheca, depth	0·24-0·27 mm.
Hydrotheca, breadth at aperture	0·12-0·15 mm.

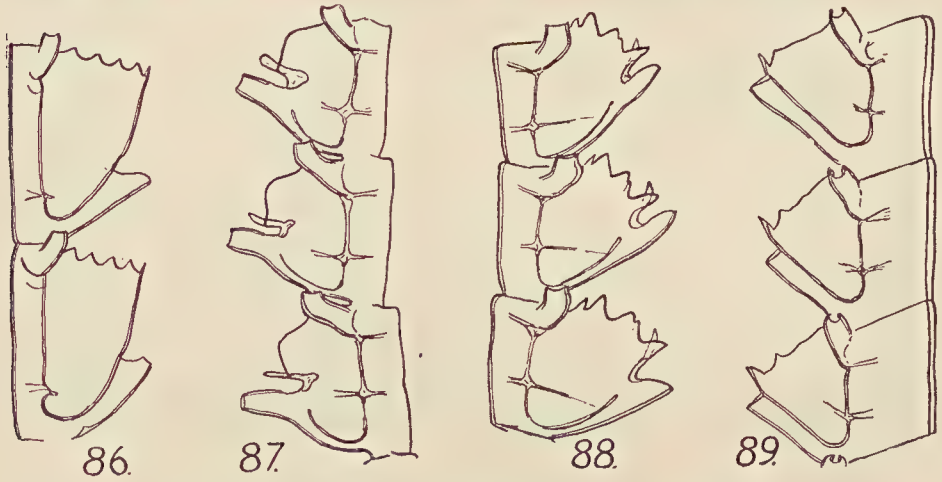
Locality: Snug, North-West Bay (September, 1949); South Arm, Derwent Estuary (April, 1947); Taroona, Derwent Estuary (August, 1949); Bicheno (May, 1949).

Distribution: Recorded from Aldinga, S.A. (Smeaton); Portland (Maplestone); Williamstown; Queenscliff.

The specimens, collected in widely separated localities, show a large range of variation in their microscopic measurements and macroscopic appearance. However, this is not inconsistent with specific characters.

The material from South Arm was growing on *Macrocystis* stipe near low-tide level; it is simple, pinnate, about 1·5 cm. high, arising from a reticulate, filiform stolon. That from Bicheno was obtained from storm-drifted seaweed.

The specimen from Snug was larger than that from South Arm, shoots being about 4 cm. long. It was found growing on *Zostera* below low-tide level.



FIGS 86-89.

Aglaophenia tenuissima Bale. Fig. 86: Portion of pinna (after Bale). *Aglaophenia plumosa* Bale. Fig. 87: Portion of pinna. *Aglaophenia parvula* Bale. Fig. 88: Portion of pinna. *Aglaophenia tasmanica* Bale. Fig. 89: Portion of pinna (after Bale).

Aglaophenia parvula Bale, 1881

(Fig. 88)

Aglaophenia parvula Bale, 1881.

Trophosome: Hydrocaulus monosiphonic, unbranched, attaining a height of about 4-5 cm.; pinnae are alternate, approximate, arising one on an internode towards the front of the stem. Hydrothecae urn-shaped, widening from base upwards, at an angle of about 40° to the pinna axis; a fold or constriction runs around cell, perpendicular to pinna axis and a little above base; margin of aperture with a single incurved, median tooth in front, four teeth on each side, the second tooth from the front may, or may not, be divided into two lobes, the back is entire and adnate to pinna. Septal ridges two, one opposite the base of lateral sarcotheca running obliquely forward, and one transverse, opposite the intrathecal fold. Mesial sarcotheca not extending beyond rim of hydrotheca, divergent, terminal and lateral apertures confluent, also an opening leading into the hydrotheca. Lateral sarcothecae short, not reaching beyond hydrotheca margin, partially adnate, free portion tapering, apertures confluent. Cauline sarcothecae resemble laterals, two on stem near base of pinna, and one on each side of axil.

Gonosome: Normal pinna replaced by a modified gonangial pinna bearing a single hydrotheca below the corbula; a joint above and below the hydrotheca, but no others on pinna are distinct. Corbulae of two kinds: (1) Six or seven pairs of broad leaflets united to form a closed sac, the distal edge of each leaflet bearing short, stout sarcothecae; from the distal side of the base of the proximal pinnule

arises a lateral spur which runs forwards parallel to pinna and bears sarcothecae on each edge. (2) Having leaflets free, both edges bordered with sarcothecae, forming an open corbula.

Dimensions:

Hydrocaulus internode (pinnate), length	0·18-0·23 mm.
Hydrocaulus internode (pinnate), diameter	0·20-0·23 mm.
Pinna internode, length	0·23-0·27 mm.
Pinna internode, diameter	0·08-0·10 mm.
Hydrotheca, depth	0·25-0·27 mm.
Hydrotheca, breadth at aperture	0·15-0·17 mm.
Corbula, length	up to 1·80 mm.
Corbula, breadth	up to 0·80 mm.

Locality: Kingston, Derwent Estuary; South Arm, Derwent Estuary (19/4/47).

Distribution: Portland (Maplestone); Queenscliff (Bale).

Referring to the mode of arrangement of the hydrothecal marginal teeth, Bale (1884, p. 166) says: 'having five teeth on each side, the second of which however is often folded behind the third, so that under a low-power they appear like one tooth'. After an examination of the specimens in this collection I am convinced that there are but four teeth on each side, the second being bi-lobed to a greater or less extent, an appearance of overlapping being due to the peculiar method of construction.

The specimen from Kingston consists of a large number of colonies growing epizoically on the elongated stalk of the ascidian *Boltenia pachydermatina*. The specimen from South Arm was growing on the stipe of *Macrocystis* near low-tide level.

Aglaophenia tasmanica Bale, 1914

(Fig. 89)

Aglaophenia tasmanica Bale, 1914b.

Trophosome: Hydrocaulus polysiphonic, sparingly branched, attaining a height of about 30 cm.; branches arise mostly in opposite pairs, with both series in one plane, originating from a primary hydrocaulus internode, replacing a pinna; pinnae alternate, arising one on an internode, at an angle of about 40° to branch, both series placed towards the front, joints somewhat oblique. Hydrothecae borne at an angle of about 30° to pinna, tapered proximally, distal part nearly cylindrical, a small fold near base on adcauline side; some hydrothecae with a small rounded tooth projecting into cavity from abcauline side a little above base; margin of aperture with a median, pointed, anterior tooth, a single triangular tooth on each side, near front, remainder sinuous but not lobed; back cut-away, adnate. Septal ridges at base of lateral sarcothecae, and at intrathecal fold. Mesial sarcothecae not reaching theca margin, adnate for whole length, with a single aperture perpendicular, or nearly so, to hydrotheca. Lateral sarcothecae tubular, projecting just above theca margin, pointing forwards and outwards; aperture round, small. Cauline sarcothecae broad, open above, two on a branch near base of pinna.

Gonosome: Gonangial pinnae usually in pairs, with first four or five internodes bearing sarcothecae only. Female: Corbula long, consisting of fifteen (or more) pairs of alternate pinnules, arising from separate pinna internodes; proximally the pinnules are narrow, but distally they expand into broad leaflets, corbula is

closed. Distal end of each pinnule extended beyond line of union giving a free edged expansion bordered with sarcothecae, and continued upwards forming a large crest above corbula having both edges free and bordered with sarcothecae. Just above origin of each pinnule, on distal side, arises a lateral projection or spur bearing two series of sarcothecae (up to seven on each side) but no hydrothecae. Male: Corbula long, with up to twenty-four pairs of alternate pinnules, which are narrow proximally, but expanded into broad leaflets distally; corbula closed for most of length but distally the pinnules become shortened and separated, until at the end they are abbreviated almost down to lateral spur. Lateral spurs similar to those of female, but bear only four or five pairs of sarcothecae.

Dimensions:

Hydrocaulus internode (pinnate), length	0·42-0·43 mm.
Hydrocaulus internode (pinnate), diameter	0·40-0·42 mm.
Pinna internode, length	0·38-0·43 mm.
Pinna internode, diameter	0·19-0·22 mm.
Hydrotheca, depth	0·36-0·38 mm.
Hydrotheca, breadth at mouth	0·21-0·22 mm.
Corbula (female), length	up to 12·5 mm.
Corbula (female), diameter	up to 2·00 mm.

Locality: Seven miles east of Cape Pillar, 100 fathoms (Briggs); Oyster Bay, 20 fathoms (Bale); Off Wineglass Bay, 80 fathoms (Briggs); Bass Strait, 70-470 fathoms (Bale).

This species has been found only in Tasmanian waters.

The dimensions are those given by Briggs (1915, p. 317). There is no specimen in this collection.

Aglaophenia armata Bale, 1914

(Fig. 90)

Aglaophenia armata Bale, 1914c.

Trophosome: Hydrocaulus polysiphonic, irregularly branched, attaining a height of about 30 cm.; a single pinna arises from each branch internode, the jointing of which may be obscure; pinnae close, alternate, divergent, joints transverse or slightly oblique. Hydrothecae borne towards the front, at about 60° to pinna axis, elongate, tubular, a strong intrathecal ridge arises near the base of the lateral sarcothecae and extends downwards about half-way across cell, nearly parallel with pinna axis; margin of aperture with large, median, anterior tooth, three lateral teeth on each side; back deeply cut-away. Two septal ridges on hydrothecate internode, one beneath hydrotheca, one beneath lateral sarcotheca, and occasionally one between. Mesial sarcotheca tubular, not extending much beyond the theca margin, straight or slightly curved, somewhat divergent, free for distal third of length, terminal and lateral apertures often confluent. Lateral sarcothecae long, tubular, parallel to axis of theca to which they are adnate for whole length, apertures may be confluent. Cauline sarcothecae two on anterior side of branch, and one behind, near origin of pinna.

Gonosome: Pinna replaced by a gonangial branch. Female: on branch, proximally, about eight to ten internodes bear modified hydrothecae, beyond is a closed corbula formed by about fifteen pairs of alternate pinnules; proximally the pinnules bear 'a projecting sarcotheca and above it a minute irregular hydrotheca (?) with two or three sarcothecae above' (Bale, 1914), this on distal side;

the distal portions of pinnules are expanded into large lobes fringed with sarcothecae. Male: bearing only about four hydrothecae proximally on the gonangial branch, corbula with much smaller foliaceous lobes.

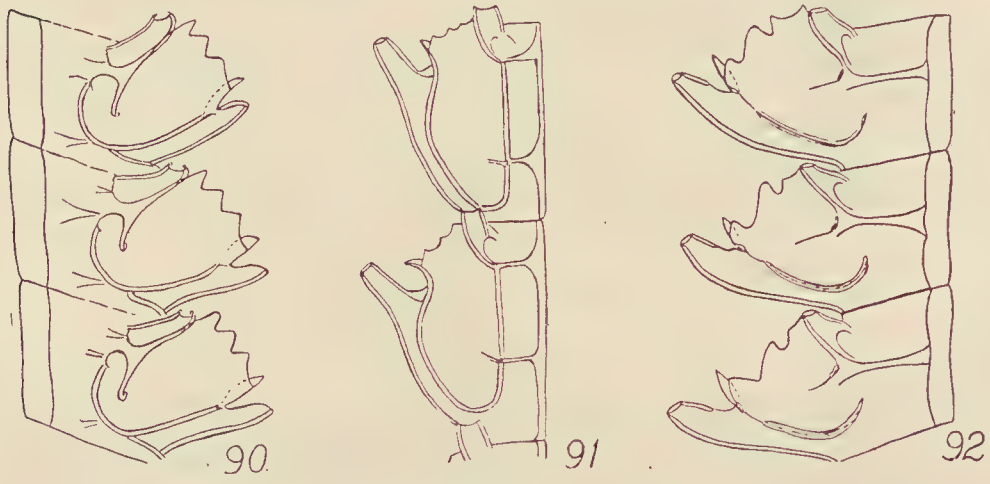
Dimensions:

Hydrocaulus internode (pinnate), length	0·26-0·28 mm.
Hydrocaulus internode (pinnate), diameter	0·22-0·24 mm.
Pinna internode, length	0·28-0·31 mm.
Pinna internode, diameter	0·24-0·26 mm.
Hydrotheca, depth	0·38-0·40 mm.
Hydrotheca, breadth at mouth	0·17-0·19 mm.

Locality: Off Wineglass Bay, Freycinet Peninsula, 80 fathoms (Briggs).

Distribution: Recorded from thirteen miles north-east of North Reef, 70-74 fathoms; Thirty-eight miles north-east of North Reef Lighthouse, Capricorn Group, off Port Curtis, Queensland, 74 fathoms (Bale).

The measurements quoted above are those given by Briggs (1915, p. 314). There is no specimen in this collection.



FIGS 90-92.

Aglaophenia armata Bale. Fig. 90: Portion of pinna (after Bale). *Aglaophenia decumbens* Bale. Fig. 91: Portion of pinna (after Bale). *Aglaophenia divaricata* (Busk). Fig. 92: Portion of pinna (after Bale).

Aglaophenia decumbens Bale, 1914

(Fig. 91)

Aglaophenia decumbens Bale, 1914b.

Trophosome: Hydrocaulus slender, polysiphonic, sparingly branched, attaining a height of about 12 cm.; branches arise from peripheral fascicle, mostly on distal portion of hydrophyton; pinnae slender, alternate, one on an internode, both series borne towards the front, joints transverse. Hydrothecae elongate, axis nearly parallel with that of pinna, a small fold present on adcauline side near base; margin of aperture with an everted median anterior tooth, four equal triangular teeth on each side, the last pair obscured by the lateral sarcothecae, back adnate. Septal ridges on thecate internodes at intrathecal fold, and at base of lateral

sarcothecae. Mesial sarcothecae extending beyond hydrotheca, somewhat divergent, adnate for two-thirds of length; free part tubular with distinct lateral and terminal apertures. Lateral sarcothecae sub-tubular, adnate, reaching to theca margin, directed forwards and outwards, terminal and lateral apertures distinct or confluent. Cauline sarcothecae large, two on branch near base of pinna.

Dimensions:

Hydrocaulus internode (pinnate), length	0·42-0·45 mm.
Hydocaulus internode (pinnate), diameter	0·19-0·21 mm.
Pinna internode, length	0·43-0·45 mm.
Pinna internode, diameter	0·08-0·10 mm.
Hydrotheca, depth	0·35-0·38 mm.
Hydrotheca, breadth at mouth	0·15-0·17 mm.

Locality: Seven miles east of C. Pillar, 100 fathoms (Briggs); Off Wineglass Bay, Freycinet Peninsula, 80 fathoms (Briggs); Bass Strait (Bale).

Bale originally erected this species for a single specimen from Bass Strait, pointing out at the time that: 'There is some doubt as to whether this species is identical with *A. brevicaulus*, Kirchenpauer'.

The measurements recorded are those given by Briggs (1915, p. 315). There is no specimen in this collection.

Aglaophenia divaricata (Busk, 1852)

(Fig. 92)

Plumularia divaricata Busk, 1852.
Plumularia ramosa Busk, 1852.
Aglaophenia ramosa Kirchenpauer, 1872.
Aglaophenia McCoyi Bale, 1881.
Lytocarpus ramosus Allman, 1886.
Aglaophenia divaricata Kirchenpauer, 1872.
?*Aglaophenia brevicaulus* Kirchenpauer, 1872.
Not *Aglaophenia ramosa* Allman, 1877.

Trophosome: Hydrocaulus slender, branched, polysiphonic, attaining a height of about 12-15 cm.; branches widely divergent, rarely in one plane, arising from peripheral fascicle; pinnae arise one on each internode, close, alternate, joints slightly oblique, both series borne towards the front of the stem. Hydrothecae set at an angle of about 45° to pinna axis, cup-shaped, with a small intrathecal ridge projecting into cell from middle of adcauline side; from ridge arises a thin fold partially dividing the hydrotheca into two; aperture large, with a long median, incurved tooth in front, four teeth on each side, back adnate. A transverse septal ridge, continuous with intrathecal ridge, crosses the internode. Mesial sarcotheca variable in length, at an angle of about 60° to pinna axis, adnate up to hydrotheca margin, with free part tapering in lateral view; lateral and terminal apertures distinct, and an opening leading into the hydrotheca. Lateral sarcothecae conical, adnate up to hydrotheca margin, with a free tubular neck directed forwards and upwards, lateral and terminal apertures distinct. Cauline sarcothecae resemble laterals, two on branch at base of each pinna.

Gonosome: Normal pinna replaced by a gonangial branch. Modified pinnae bear from 15-20 pairs of alternate pinnules; pinnules each borne on a short internode, and each with two lateral series of sarcothecae similar to hydrothecal laterals, but larger: sarcothecae opposite, except proximally where the first two

on the distal side of pinnule lack corresponding ones on the proximal side; jointing of pinnules obscure; two sarcothecae present on pinna at base of each pinnule. The two series of pinnules are arched, meeting at top, forming an open corbula. A single hydrotheca borne proximally on the pinna below the corbula.

Dimensions:

Hydrocaulus internode (pinnate), length	0·29-0·33 mm.
Hydrocaulus internode (pinnate), diameter	0·28-0·29 mm.
Pinna internode, length	0·26-0·28 mm.
Pinna internode, diameter	0·17-0·19 mm.
Hydrotheca, depth	0·24-0·26 mm.
Hydrotheca, breadth at aperture	0·17-0·19 mm.

Locality: Storm Bay (Briggs); Oyster Bay, 60 fathoms (Bale); Off Wineglass Bay, 80 fathoms (Briggs); Bass Strait (Busk); George Town (Kirchenpauer).

Distribution: Recorded from Swan Island, Banks Strait (Busk); Wilson's Promontory, Victoria (Kirchenpauer); Portland; Griffiths' Point; Queenscliff; Williamstown, Victoria; Brighton, South Australia; Port Jackson, N.S.W. (Bale); Victoria (Marktanner-Turneretscher); Station 54, within Jervis Bay, N.S.W., 10-11 fathoms (Ritchie).

The measurements are those given by Briggs (1913, p. 316). There is no specimen in this collection.

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Pap. & Proc. Roy. Soc. Tasmania, 1949 (15th September, 1950)

A Preliminary Description of *Fabia hickmani*, sp.nov. (Pinnotheridae)

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(Read 1st November, 1949)

Pea crabs are very frequently found inhabiting mussels in the large beds of these Lamellibranchs in the estuary of the River Derwent and other places in Southern Tasmania. The mussel from which the specimens on which the present description is based is *Mytilus planulatus* Lam. The mussel beds are found at or about the tide level for 'low high' water. Most of the specimens were collected at Blackman's Bay but some came from the other side of the estuary at Bellerive, Ralph's Bay and South Arm while specimens were collected outside the estuary at Dodge's Ferry and Dunalley. All these latter specimens were used for comparative purposes only.

The species exhibits the sexual dimorphism common to the family, the adult male being considerably smaller than the adult female. The female shows five growth stages of which the first is similar in size and appearance to the male. The later stages exhibit progressively increasing difference from the male in both size and appearance. These stages correspond closely to those for *Pinnotheres pisum* (Pennant) as described by Atkins (1926).

Females of this species have been kept alive easily by placing them in a well aerated aquarium tank with a supply of colonial diatoms of a Euschizonema-Melosira association. The crabs fed on the diatoms using the chelae in the normal feeding method of crabs.

One specimen of *Halicarcinus ovatus* (Stimpson) was found inside a mussel. This was probably accidental as crabs of this species are common in the mussel beds.

Genus **Fabia** Dana

'Carapace smooth, membranous, subquadrate with longitudinal sulci leading leading back from upper margin of orbits and enclosing median area. Outer maxilliped with ischium rudimentary and merus large, last joint of palp attached to preceding one on inner margin. Legs slender; 2nd walking leg longest.'

The specimens fall into this generic description with the exception of the longitudinal sulci. In some specimens these may be absent or very rudimentary.

Male

The male crabs have a hard, rounded stone-like carapace. The average width of the carapace is 4·5 mm. though some individuals may measure 5·0 mm. across the carapace. There is a slight ridge of hairs round the outer margin of the carapace. The colour in life is a flat creamish white. The animal is opaque. In spirit the older individuals assume a purplish or blue colour on the anterior

region of the carapace, whereas the younger individuals are brown or red-brown in colour. There is a small, flat anterior rostrum and posteriorly, in most individuals, there are two lateral notches above the last pair of walking legs. The ventral thoracic surface is slightly convex and bears the abdomen tightly folded into a median groove. (Fig. 1.) The posterior ventral surface of each thoracic segment bears a pointed projection which extends laterally a short distance behind each walking leg.

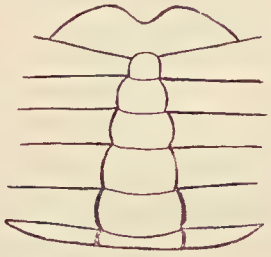

FIG. 1.—Diagram showing width of abdomen of Stage 1 female of *Fabia hickmani*. × 9.

The walking legs are well developed and the chelae are strong and of normal dimensions for a crab of this size. All the walking legs bear a dorsal and ventral fringe of setae on all segments. The setae are more numerous and strongly developed on legs 2, 3 and 4. The biting surfaces of the chelae bear strong setae.

The abdominal appendages are small with the exception of the intromittent organ.

FEMALE

Crabs of this species show the five stages described for *Pinnotheres pisum* (Pennant) by Atkins (1926).

Stage 1

This is similar to the first stage described by Orton (1920) and Atkins (1926) for *P. pisum*. Similar stages have been described for *P. maculatus*, *P. margarita*, *P. taylori* and *P. concharum* by Rathbun. The female at this stage is virtually indistinguishable from the male and it is only by careful examination of the abdominal appendages that the sex may be determined.

Carapace width between 2·25 mm. and 4·0 mm. This is slightly smaller than the corresponding sizes for *P. pisum* (Atkins loc. cit.). In this stage and Stage 2 there is considerable variation in the shape of the carapace which varies between round and oval. In the latter case the long axis forms the width of the carapace. A similar condition is to be seen in the male. There may or may not be notches in the posterior lateral border of the carapace in the position noted in the description of the male.

All the individuals of this stage examined were of very similar appearance to the male with the exception of one specimen in which the fringes of setae on the dorsal and ventral surfaces of the walking legs were poorly developed. The fringe around the margin of the carapace was normal in this individual.

The abdomen is very similar to that of the male. In both sexes the penultimate segment is convex on the lateral margins and the preceding segments are slightly concave. The spermathecae in all individuals of this stage were empty.

This stage comprised about five per cent of the total number of females collected.

Stage 2

Carapace width from 2·5 mm. to 5·25 mm. In external appearance the crab still resembles the male but the carapace is soft and the spermathecae are in various degrees of impregnation. Atkins (1926) has pointed out the difficulties of the male achieving impregnation of both spermathecae but in several of the specimens examined both spermathecae were full. It is not possible to say whether this was the result of one or two copulatory acts by one or more males. The abdomen is broader than in the male and Stage 1, and is intermediate between the latter conditions and Stage 3. (Fig. 2.)

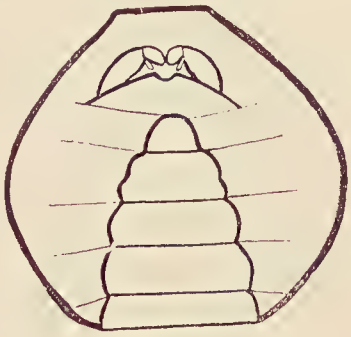

FIG. 2.—Stage 2 female of *F. hickmani*. × 6.

The colour of the eyes is reddish with the pigmented area somewhat reduced. The colour of the crab is a translucent white.

Stage 3

Carapace width from 4·5 mm. to 7·5 mm. The two varieties of this stage as described by Atkins (1926) for *P. pisum* have not yet been distinguished for this species. The condition *(b)* in *P. pisum* in which the abdomen is slightly wider than in Stage 2 and reaching further forward has not been found.

The spermathecae were found either full or empty in different individuals. The abdomen is broad being nearly equal in width to the sternum. (Fig. 3.) The abdominal appendages are more fully developed and are hairy.

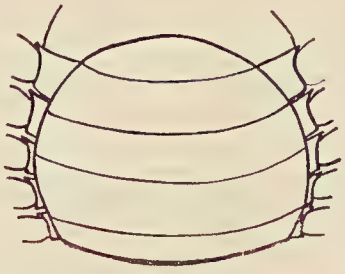

FIG. 3.—Stage 3 female of *F. hickmani*. × 5.

A noticeable feature of this stage was the great reduction of the fringes of setae on the limbs and around the edges of the carapace. The fringe of setae across the anterior ventral margin of the thorax is first distinguishable at this stage. This fringe runs across the ventral surface immediately anterior to the posterior of the abdomen. The function of this fringe appears to be the retention of ova within the fold of the abdomen. In this it is assisted by the fringe along the posterior of the abdomen.

This stage is very rare, less than one per cent of all the small crabs being taken in this stage. This rarity supports Atkin's observation that the female probably passes through the early stages very rapidly. It seems likely that the stages after impregnation are passed through more rapidly than the first stage.

Stage 4

Carapace width from 5·5 mm. to 9·5 mm. This is the earliest stage at which a female has been taken in berry. The carapace is not as firm as in Stage 5 though it is more firm than in Stage 3. Through the carapace the ovary may be seen in various stages of development. The fringes of setae around the carapace are well developed. Some individuals have red chromatophores scattered on the dorsal surface of the carapace, while in others these cells are absent or poorly developed.

The thoracic setae all bear dorsal and ventral fringes of setae. The chelae are small. The abdominal limbs are well developed.

Stage 5

This is the adult female. Carapace width from 6·5 mm. to 13 mm. The abdomen overlaps the mouth and the basipodite of the walking legs. This may not be apparent when ova are being carried as the abdomen is then distended.

The body is firmer than in Stage 4 but it is still soft and membranous. The carapace is sub-circular in form and the width of the abdomen is five-fourths of the width of the carapace. The abdomen is very rounded. Except on the walking legs, lateral abdominal surface and the ventral thoracic surface, the animal is devoid of setae. The first walking leg bears a weak, calcified chela. The fringe of setae on the first walking leg is found on the ventral surface only. The setae on the dactylopodite and propodite are more numerous and extend all along the inner border of the claw. The cutting surfaces of the claws bear strong setae. The second walking leg has setae on the ventral surface of all segments except the propodite and carpopodite. The setae are not very strong and are few in number. The third walking leg bears a few fine setae ventrally on all segments except the carpopodite. The meropodite bears a fringe of strong setae on the dorsal surface. The fourth walking leg is similar to the third except that the dactylus is not as heavily covered with setae on its ventral surface. The fifth walking leg bears very few setae except on the dorsal surface of the meropodite which carries a row of strong setae.

The carapace is convex and smooth with a very small rostrum which does not project in front of the eyes. The carapace is soft compared with that of the male but is slightly stiffer than in Stages 3 and 4. It is sub-rectangular in shape the long axis of the rectangle being at right angles to the antero-posterior axis of the body.

On the ventral thoracic surface is a row of setae anterior to the abdomen. These were noted in Stage 3. The abdomen bears a slight median keel.

The eyes exhibit considerable variation in the amount of pigment they possess. Some of the individuals collected had very little pigment whereas others showed pigmentation over almost the whole surface of the eye. The pigment may be either black or dark red. The eyes are reduced.

The mandibles are strong and bear a large tooth and three smaller teeth in a row on the cutting edge. The external ramus has a number of setae on the lower border and three long sub-terminal setae. In general form this appendage closely resembles that of *Pinnotheres pisum* (Pennant), the principal difference being in the number of teeth. (Fig. 4.)

FIG. 4.—Mandible of *F. hickmani*. × 35.

The first maxilla bears setae on both the exopodite and the endopodite. The second maxilla is similar in form to the first but bears serrated spinous setae on the outer lateral border.

The maxillipeds are all flattened. The third maxilliped has a very large meropodite with a very much reduced ischiopodite. The endopodite bears a long, strong apical seta.

The colour of this stage is a dirty cream with the ovary and the hepatic region showing through the carapace as patches of either purplish or red colour. If ova are being carried the abdomen is of a dark red colour. If no eggs are being carried the alimentary canal stands out as a dark line. The number of ova carried varies considerably. The summer average is about 8500. The species appears to breed all the year round with spring and autumn maxima. In winter fewer eggs are carried.

INFECTIONS OF MUSSELS

It is hoped to carry out work on the relation between the size of crab and the size of the host mussel. The percentage infection is very high. In some old mussels at Blackman's Bay and others dredged in Ralph's Bay the figure is 100 per cent.

It was noted by Atkins (1926) in the European species *P. pisum* that two females have never been found in the mussel. In the present species two females were found in one mussel. One of the females was Stage 4 and the other was Stage 5. It is fairly common to find an adult female in a mussel with a Stage 1 or 2 female. It is also common to find male and female together in the same mussel. The highest frequency of occurrence of two females occurs in mussels of 7 cm. size.

The percentage of males is high compared with the European species. Of all the young specimens about 75 per cent of individuals were males.

In the course of fairly extensive collecting in the mussel beds at Blackman's Bay I have never encountered a free living male. The mussel beds can be fairly thoroughly searched at 'low low water'. This absence of the free living male points to the fact that in this species the male habitually lives in a mussel and only changes his abode to search out another female. Many mussels have been taken with only a male inside them. The evidence is not conclusive as collecting when the beds are covered by water is a hit-or-miss business and although no free males have been taken at that stage of the tide it is possible that they do exist.

In view of the confirmed record of *Pinnotheres pisum* from New Zealand (Richardson, 1949) it is of interest to note that the species has not yet been found in Tasmania.

Summary

The male crab is described and the five stages of the female are also described. The stages correspond closely to those described by Atkins (1926) for *P. pisum*. The number of mussels infested by crabs is very high reaching 100 per cent in some places. Males form a large proportion of the small crabs caught. Two females have been taken in one mussel but the male has never been found anywhere other than in a mussel. *Pinnotheres pisum* (Pennant) has not been found in Southern Tasmania.

I am indebted to Prof. V. V. Hickman for advice during the preparation of this paper and for reading the typescript.

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Pap. & Proc. Roy. Soc. Tasmania, 1949 (15th September, 1950)

A Revised Description of *Dolichopera macalpini* Nicoll, 1914

(PLAGIORCHIIDAE-TREMATODA)

By

Peter Crowcroft

(With One Plate)

In March, 1948, Mr. J. de Bavay collected two tiger snakes (*Notechus scutatus* Peters) in the vicinity of the Arthur Lakes. The alimentary and respiratory systems were fixed in Bouin's fluid. Upon opening the lungs Mr. de Bavay observed the presence of numerous trematodes and handed all the fixed material over to me in order that I might identify them.

Dolichopera macalpini Nicoll, 1914, appears to be the only fluke reported from the tiger snake. It is briefly described, but not named by D. McAlpine (1891), whose material came from the gullet, the anterior part of the stomach, the trachea, and the lung of a copper-head snake (*Denisonia superba* Günther). Nicoll (1918) notes than in 1911 Dr. Georgina Sweet of Melbourne University sent him specimens of this trematode said to have come from the intestine of the tiger snake and the lung of the copper-head snake. He also mentions the collection in 1910 by Dr. Burton Cleland of an apparently similar form from the peritoneum of an unidentified snake on Flinders Island. In the two tiger snakes from the Arthur Lakes in Tasmania the parasites are confined to the respiratory system.

McAlpine's observations are clear, but inadequate by present-day standards. Nicoll's attempt to redescribe the species he had previously named from McAlpine's description, adds very little information. Neither author provides an illustration of the species. I think there is no doubt that the Tasmanian specimens should be assigned to *Dolichopera macalpini*, but several differences, probably due to omissions from the earlier descriptions, may indicate variation between the Tasmanian and mainland forms.

Whole mounts used in compiling the following description were stained with alum carmine. Longitudinal and transverse sections were stained with Ehlich's haematoxylin and eosin. The work was commenced in the Zoology Department of the University of Tasmania during the tenure of a Commonwealth research grant, and completed at the Bureau of Animal Population, Oxford University.

Family PLAGIORCHIIDAE Lühe, 1901

(syn. LEPODERMATIDAE Looss, 1901)

Dolichopera macalpini Nicoll, 1914

External Features

These trematodes are fairly large, measuring up to 4·0 mm. long and 1·6 mm. broad. The smallest (non-gravid) specimen found measured 0·8 mm. x 0·5 mm. Three progressively larger individuals are illustrated (Figs 1-3). In section the body is concave ventrally and convex dorsally. The anterior end bears a prominent

pre-oral lip, while the posterior extremity is produced into a small protruding fleshy knob. The pre-oral lip is not mentioned in the accounts of McAlpine and Nicoll. The posterior protuberance is not retractile and does not resemble the ecsoma of the *Heminrinae*. In strongly flexed specimens it is directed forwards and is not visible from the dorsal aspect. The oral sucker measures up to 0·6 mm. x 0·49 mm. The mouth is directed forwards and downwards and the anterior rim of the sucker protrudes from the pre-oral lip (Fig. 4). The acetabulum is situated just behind the middle length. It is slightly smaller than the oral sucker, measuring up to 0·47 mm. in diameter. In form it is a simple cup, the gape of which may be elongated transversely or longitudinally. The rim of the acetabulum projects slightly from the ventral surface. A simple pore, at the level of the posterior border of the oral sucker, and about half-way between the mid-line and the lateral body margin of either the left or the right side, leads into a short genital atrium. This appears to be merely an invagination of the ventral surface caused by the retraction of the cirrus sac. When the sac is thrust forward, the male and female apertures lie side by side at the end of a stout papilla. The relative prominence of the genital atrium appears to depend on the degree of contraction of the specimen. The excretory pore is situated at the extremity of the knob-like 'appendage' which projects from the hind margin. A further small pore, leading to Laurer's canal, occurs in a medial dorsal position approximately 0·6 mm. from the excretory pore. The cuticle is thick and spinous. Ventrally the spines, measuring 0·018 mm. extend almost to the posterior extremity. Dorsally they are weaker and do not extend beyond the middle length.

Alimentary System

According to Nicoll (1918), the pharynx is contiguous with the oral sucker, and the oesophagus 'is extremely short and divides almost immediately into the diverticula'. McAlpine (1891) states that the mouth ' leads into a pharynx, which very soon enlarges into a thickened muscular body, succeeded by a comparatively short gullet, which is thin-walled'. My sections reveal the presence of a well developed prepharynx followed by a muscular pharynx which measures approximately 0·18 mm. both in length and diameter. The pharynx leads into a weakly muscular oesophagus of similar length (Fig. 4). This corresponds to McAlpine's description, when the different terminology is taken into account. In whole mounts and contracted specimens the oral sucker and the pharynx appear contiguous due to the dorsad displacement of the latter (Fig. 4). The two gut rami diverge from the oesophagus and run backwards, close to the dorsal surface, at some distance from the lateral body margins. Near the posterior extremity they descend and lie adjacent to the outer margins of the testes. They may terminate in this position, or they may pass beyond the testes and curve slightly inwards behind them. The termination is commonly slightly expanded. The rami are comparatively narrow tubes bounded by a deeply staining layer containing large nuclei. No muscle fibres or continuous membranous walls appear to be present.

Reproductive System

Male: The testes are two irregularly lobed but entire bodies, lying side by side near the posterior end of the body. They measure up to approximately 0·45 mm. x 0·23 mm., being elongated in the direction of the animal's length, and are bounded laterally by the gut rami. Nicoll (1918), describes the testes similarly but states that the left is in advance of the right. This is not consistently so in my material although in whole mounts either testis may appear slightly in advance of the other. A vas deferens leaves the antero-dorsal surface of each

testis and the two ducts converge to meet, but not fuse, above the acetabulum. Together they run obliquely forward suspended within the spacious uterus by a 'mesentery' formed by a folding of its dorsal wall, and enter the posterior tip of the cirrus sac. The cirrus sac is comparately large measuring up to 1·0 mm. long and 0·3 mm. in diameter. It has the form of a slightly sinuous or simply curved cylinder with rounded ends. There is no doubt that this is the organ McAlpine (1891) refers to as the vesicula seminalis. Nicoll (1918) states of the sac's contents: 'It contains a large vesicula seminalis, a short pars prostatica and a moderately long ductus ejaculatorius' but records no actual dimensions. In similar terms I should describe the Tasmanian specimens as possessing a *small* seminal vesicle and a *long* pars prostatica. The seminal vesicle is a weakly muscular bipartite sac situated centrally within the posterior end of the cirrus sac. Its two approximately equal compartments communicate through a narrow aperture in a muscular partition (Fig. 4). Overall the vesicle measures approximately 0·29 mm. long and 0·14 mm. in diameter. The anterior compartment narrows into a slender tube which expands abruptly into the cylindrical pars prostatica. This measures 0·8 mm. long and 0·16 mm. in diameter. Its wall contains weak longitudinal muscles and it is almost filled by the lining of tall empty-looking 'cells'. At its anterior end the pars prostatica leads into the muscular ejaculatory duct which traverses the remaining length of the cirrus sac to open into the genital atrium, immediately adjacent to the female opening. No cirrus is differentiated, the protruded end of the cirrus sac forming a genital papilla. The peripheral spaces within the cirrus sac are occupied by the tightly-packed cells constituting the prostate gland (Fig. 4).

Female: In whole mounts the ovary lies on or slightly to the right of the mid-line, near the dorsal surface, and immediately behind the level of the acetabulum. In unflattened specimens however, it may lie mid-way between that organ and the posterior extremity of the body. It is an irregularly ovoid body measuring 0·25 mm. in greatest diameter. Ventrally the ovary leads into an oviduct which is proximally expanded to form a ciliated ovicapt. The oviduct turns posteriad and connects laterally with the large thin-walled receptaculum seminis (Fig. 5). Shortly after, Laurer's canal is given off ventrally. This winds a sinuous course backwards through the dense tissue above the excretory vesicle. Beyond the testes it turns abruptly dorsad and communicates with the exterior by a median dorsal pore. The circular muscles of the canal are very strongly developed, and it is lined by cuticle for at least a considerable distance from the pore. After giving off Laurer's canal the oviduct receives a short duct from the median yolk reservoir. It then turns dorsad and expands into the ootype. Large gland cells are loosely packed about this region and constitute the 'shell' gland. Beyond the ootype the female duct continues as the uterus, which gradually expands into the relatively enormous tube whose convolutions occupy the greater part of the animal's bulk. Nicoll (1918) describes the uterus as a narrow highly convoluted tube. While this is true of the proximal convolutions behind the ovary, in front of that organ the diameter of the uterus is relatively enormous and its convolutions relatively few. The uterus extends forwards beneath the cirrus sac and almost at the level of the genital pore, terminates in a very short broad metraterm which runs directly forwards into the genital atrium. The innumerable eggs are elongate-oval in form and measure 0·036 mm. long and 0·02 mm. in diameter. The shell is yellowish brown in colour but in the mass the eggs appear dark brown to almost black. The shell has a circular operculum at one end. The yolk follicles lie in two lateral groups extending from the level of the acetabulum almost to the posterior end of the body. In flattened whole mounts

they are, as Nicoll describes them, confined to the outer side of the intestinal diverticula, but sections show that they lie dorsal to the rami and may extend over them into the intercaecal region. The follicles measure approximately 0·05 mm. x 0·1 mm. and discharge into main longitudinal collecting ducts lying between the gut rami and the lateral body margins. At the level of the ovary transverse ducts pass over the gut and meet behind the ovary. The expanded junction of the pair of transverse ducts with the central duct leading to the oviduct forms a T-shaped yolk reservoir.

Excretory System

The median excretory vesicle extends directly forwards from the pore, separates the testes, and bifurcates immediately behind the ovary. In large specimens the vesicle may be displaced to one side by the uterus. A further development, or a possible artifact caused by contraction during fixation, is the prolapsus of the uterus into the excretory vesicle.

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Nicoll, W., 1914.—The Trematode Parasites of North Queensland. I. *Parasitology 6*, pp. 333-350.

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PLATE I

Fig. 1.—*Dolichopera macalpini* Nicoll, whole mount approximately 4 mm. long, from the ventral aspect. Contents of the uterus omitted.

Fig. 2.—*D. macalpini* Nicoll, whole mounts approximately 2·6 mm. long, from the ventral aspect. Contents of the uterus omitted.

Fig. 3.—*D. macalpini* Nicoll, whole mount of non-gravid individual approximately 1 mm. long, from the ventral aspect.

Fig. 4.—*D. macalpini* Nicoll, vertical longitudinal section of the forebody. Contents of the uterus omitted.

Fig. 5.—*D. macalpini* Nicoll, diagram of female complex reconstructed from serial sections. Drawn from the posterior aspect.

ac, acetabulum; *cs*, cirrus sac; *cut*, cuticle; *gap*, common genital aperture; *int*, intestine; *lc*, Laurer's canal; *oes*, oesophagus; *os*, oral sucker; *ov*, ovary; *ovc*, ovicapt; *ovd*, oviduct; *pg*, prostate gland; *ph*, pharynx; *pl*, preoral lip; *pp*, pars prostatica; *res*, yolk reservoir; *rs*, receptaculum seminis; *sh*, cells of the 'shell' gland; *sv*, seminal vesicle; *tes*, testis; *ut*, uterus; *vd*, vas deferens.

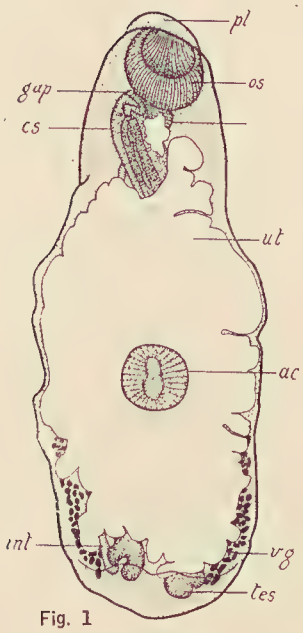


Fig. 1

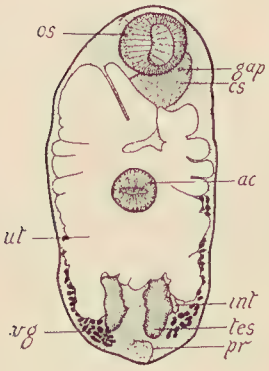


Fig. 2

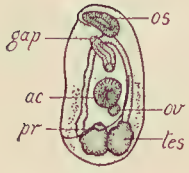


Fig. 3

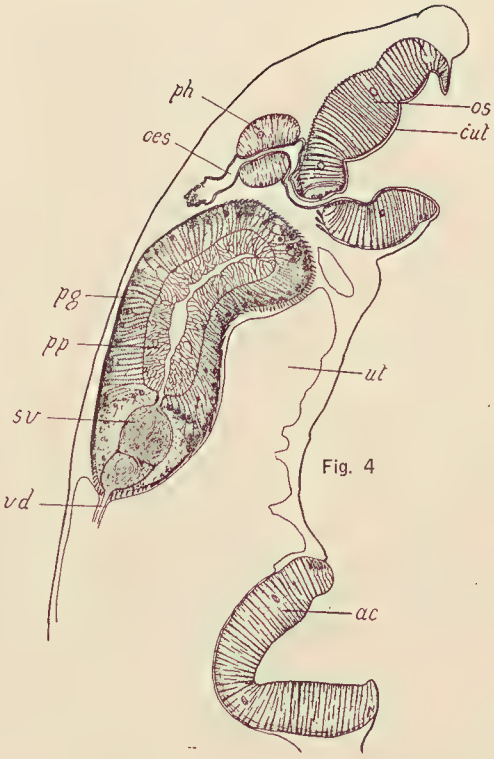


Fig. 4

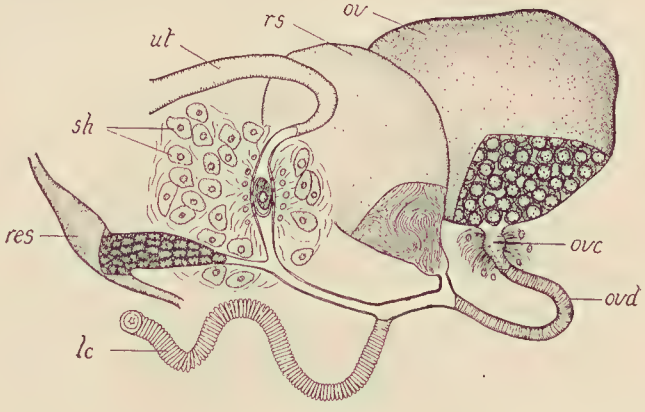


Fig. 5

Pap. & Proc. Roy. Soc. Tasmania, 1949 (15th September, 1950)

The Story of Mary Mack and her Daughter Elizabeth Mary Mack

By

W. H. Hudspeth

(Read 4th October, 1949)

Among the actors who played minor roles in the drama of Tasmanian history during the early years of the little Settlement on the banks of the Derwent were two women, whose names are worthy of remembrance, not merely for their own sakes but because of their association with a man who played a leading part, the Rev. Robert Knopwood first Chaplain of the infant Colony. They were Mary Mack and her daughter, Elizabeth Mary, sometimes called 'Betty' or 'Betsey' Mack.

Of Mary Mack little is known, except that she was a young woman in her early twenties when she first came on to the scene. She probably came out in 1803 on board the 'Calcutta' with Lt. Col. David Collins to Port Phillip, and thence in 1804 to Hobart Town. But her name does not appear in any of the lists available in the Mitchell Library, or elsewhere, to which I have had access.

Collins brought with him a detachment of Royal Marines, who, if of good conduct, were allowed to quit the service on their return to England, or to be discharged at the expiration of three years after landing in Australia, if they desired to remain and become settlers. Between Mary Mack and one of these Marines an acquaintance began which ripened into a romance, with a not unusual, but tragic sequel. The young man returned to England, leaving her behind with an infant daughter of eight months old. The poor girl was destitute, and Bobby Knopwood, in the kindness of his heart and out of compassion for her distress, took her and her baby under his roof at Cottage Green, where she remained until her death a few months later, at the age of 27. She was buried in St. David's Cemetery, and over her grave was erected a simple monument, a slab of Tasmanian Blue-Gum, on which were inscribed the following words:—

IN MEMORY OF
MARY MACK WHO
DEPARTED THIS LIFE
Octobr 16th 1808
Aged 27 YEARS.

This monument has had an unusual history. As the years went by, the old St. David's Cemetery fell upon evil times, and became the haunt of thieves and larrikins and other undesirables, who defaced the headstones and their inscriptions. One of Mary Mack's descendants noticed that her tablet had been damaged, and rescued it and presented it to the Tasmanian Museum. Years afterwards it was sent to England, to be exhibited there as a sample of the durability of Tasmanian timber. Upon its return it was again housed in the Museum, where it has been ever since. The wood is still in perfect preservation, 140 years after it was first cut, although it bears obvious signs of desecration by sacrilegious hands. It is the second oldest existing memorial of those in St. David's Cemetery, and one of the very few tangible links still left with those far-off days of Tasmanian history.

Mary Mack's infant child was born on 30th August, 1806, and in due course was baptised with the name of 'Elizabeth Mary'.

Apart from family tradition our only source of information about her is the diary of Robert Knopwood. Unfortunately he was a bad diarist, with little literary ability, and very rarely indulging in any personal opinions or comments, most of the entries being bare laconic statements of fact. And so, in perusing his diary, we must be prepared to read between the lines in order to discover the motives and background behind the incidents recorded.

The first entry about the child is dated 14th August, 1807, when he wrote 'This afternoon little Mary, a child of one year old, came to my house, and Mrs. McCauley [Knopwood's housekeeper] took her, her mother being a poor distressed woman'. Mrs. McCauley kept house for Knopwood until she went to live with her husband on his farm at Muddy Plains, as Sandford was then called. Knopwood was very often hazy about dates and ages. He was never quite certain even of his own age, and in the case of little Betsey Mack he contradicted himself, and gave her different ages at different times. But he always insisted than 30th August was the date of her birthday. The mother Mary Mack, died fourteen months after they took refuge at Cottage Green, and the poor orphan child was then formally adopted by Knopwood and brought up as his own. The volumes of the diary for the next six years, 1808 to 1814, are unhappily missing, and we do not hear anything more of her until September, 1814, when he recorded, 'Little Betty and self walked to Newtown to dine with the Whiteheads'. The Whiteheads were great friends of Knopwood and had a farm near Cornelian Bay, and as she was then only eight years old she must have been a sturdy child to walk so far.

On 30th August, 1815, there was an entry 'My little orphan's birthday, seven years this day' (she was actually nine) and thereafter there were frequent entries of subsequent birthdays, which were always occasions for special celebrations.

On 28th March, 1816, Mrs. Hayes, the wife of one of Governor Collins' free settlers, gave a ball for her grand-daughters, the two Miss Bowens, to which Betsy was taken, her first dance and 'stays all night'.

On her tenth birthday, 30th August, 1816, she was given some handsome presents, a cow from Lt. Governor Davey, another from Edward Lord, and a third from Knopwood himself. They were rather odd gifts for a child of her tender age but probably they were taken care of at the McCauley farm, and brought her in some pocket money.

On 24th March, 1818, he took her for a water picnic to Crayfish Point, accompanied by three men and four native girls. The latter dived for the fish and caught a 'great many'. The following month they had another outing to the same spot, with two native girls to do the fishing. There were other excursions, to Knopwood's farm at the Cove, and to the McCauley farm at Muddy Plains. Those early years must have been bright and happy years for the little girl, as well as for her adoring foster-father.

But she was now twelve years old, and it was time to think of more serious things than crayfishing and bush walks, she must be educated and brought up as a young lady should be. So in September, 1819, Knopwood took her in his boat across the river to Clarence Plains, to inspect the Seminary for Young Ladies at Rokeby, kept by Mrs. Speed. We know nothing about this establishment, but apparently the inspection was satisfactory, at any rate on the surface, and

Betsey was duly placed under the care of its proprietress and remained there for about three years. She was visited from time to time by her guardian, and on at least one occasion, on 23rd October, 1822, by the Governor's Lady (politely referred to by Knopwood as 'Mrs. Sorell') who he says, 'was very much delighted by Mrs. Speed's manner and the neatness of the beds and rooms'. But, alas, we suspect that this delightful manner and neatness were only window-dressing, and concealed methods and practices that would have done credit to Mr. Squeers of Dotheboys Hall. For in January, 1823, there was this entry—'From her ill-treatment I determined to take my orphan child from school'. From this bald statement we are left to imagine what poor little Betsey's trials and experiences must have been. How thankful she must have been to get back to the gentle loving atmosphere of Cottage Green!

But it was not to be for long. She was now sixteen and growing up, and Romance was waiting around the corner. Cinderella had found her Prince. He was a young man named Henry Morrisby, who lived with his father at Clarence Plains. He had probably met her at the Rokeby School, or at Muddy Plains. They fell in love with one another and became engaged. Knopwood at first seemed very happy about the matter, although reluctant to part with his beloved companion, and readily gave his consent to the match. He described Henry Morrisby as 'a young man of excellent character' and busied himself with elaborate preparations for the marriage. He officiated at the wedding, which took place at the old St. David's Church on 20th October, 1824, and entertained the guests at breakfast at Cottage Green, and then took the happy pair in his boat across the Derwent to spend their honeymoon at the McCauley's farm. He gave them wedding presents of cattle and sheep, and persuaded Lt. Governor Sorell to grant them a farm of their own at Muddy Plains. But after it was all over the old man went back sadly to his empty house, overwhelmed by the realization of his loneliness and with gloomy forebodings for the future. 'Very unwell' he confided to his diary 'at the departure of my only comfort, my dear adopted daughter, E. Mack'.

In October the following year (1825) Cottage Green was to witness another interesting event, the birth of Betsey's first child. It was a son, who was christened 'Robert Henry' on 14th November. Knopwood gave a grand dinner party to celebrate the occasion, bringing up from his cellar, wine which, 'had been in the house from 12 to 14 years'. For the next year or two things apparently went well with the young couple. Robert and his mother often came to Hobart Town to visit the old man, the boy was vaccinated with 'Cow Pox' and his first birthday is recorded in the diary. But in 1829 there was a hint of trouble at Muddy Plains. In an entry of 10th May of that year Knopwood wrote 'At Clarence Plains. In the afternoon returned to Mrs. Morrisby. He behaved "malum" to her'. (Throughout his diary he dropped into Latin when he had anything particularly unpleasant to record.) This was followed, a few days later, by another remark, 'At Mrs. Morrisby's. He was returned and behaved very ill to my poor dear girl. I took her part. His conduct is very bad'. And again, on 2nd June, 'My poor dear girl, Mrs. Morrisby—E. Mack that was—and her little boy were obliged to return home. Mr. Morrisby would not allow her to remain. His treatment of her is shameful'. This must have been a particularly bitter blow for Knopwood, as June 2nd was his birthday, and Betsey and the boy had gone over to celebrate it with him. However the breach was healed a few months later, when he says that Mr. Morrisby had come over to tea at Cottage Green, and 'we made it up'. Knopwood seldom bore resentment

against anyone for long, except for Colonel Arthur, whose treatment of him he never forgave or forgot. The last day of that year was spent with his beloved Betsey and her friends Mrs. and Miss Chase, who sat up with him until midnight to see the Old Year out and the New Year in, and to wish him a Happy New Year.

But their good wishes were not fulfilled, for the new year was to see the close of what was probably the saddest chapter of Bobby Knopwood's long life. He was approaching his 70th year, and had for some time been in serious financial difficulties. His creditors had seized and sold most of the valuable land granted to him on his arrival in the Colony. He had been compelled to resign his post as Chaplain, to make room for Rev. William Bedford, and to take up temporary duty at New Norfolk. He had expected to be appointed permanently to that Parish, but his hopes were dashed by the arrival from England of the Rev. Hugh Robinson, armed with the appointment, and he himself was relegated to Clarence Plains. He was still occupying Cottage Green, but in 1829 that, too, was sold to one Henry Jennings, who soon after disposed of it to Lt. Governor Arthur. Jennings had assured him that he could stay on there as long as he liked, but this did not suit Arthur's plans, and in 1830 the poor old man was forced to leave his beloved home and to take up residence in his New Parish, in a tiny uncomfortable cottage not far from Kangaroo Point, on the road to Howrah. By April of that year he had packed up all of his possessions and moved into his new abode. He was most unhappy, and from time to time would walk up to the Bluff and gaze wistfully across the water, dreaming of the days that were no more.

And then, six months later, came the final, shattering blow. On October 19th, 1830, Mrs. Morrisby, who was expecting her second baby, invited him to dine with her next day—the anniversary of her wedding—but he was unwell and had to decline the invitation. The following morning, at nine o'clock, he was horrified to receive the news that she had died shortly after giving birth to a baby daughter. She, whom he loved more than anything in the world, had gone, at the age of 22 and left him to face the future alone!

For the next few weeks his diary was full of laments over this untimely and unexpected loss. On 22nd October he wrote—'At home all day in a most melancholy state. Many friends both came and sent to know how I was, including Rev. Bedford to settle about the funeral'. On 23rd October—'Preparing for the funeral of my dear and ever-regretted Elizabeth Mary Mack . . . in fact my only comfort'. There is no account of the funeral in the diary, but on the 26th he says, 'This morn early I visited the grave of my dear and ever-regretted late E. Morrisby', and on 5th November, 'Rode to Clarence Plains. Called upon Mrs. Maum, and gave her two gown pieces for her attendance upon my dear and ever-regretted late E. Morrisby. Afterwards I visited the Tomb'.

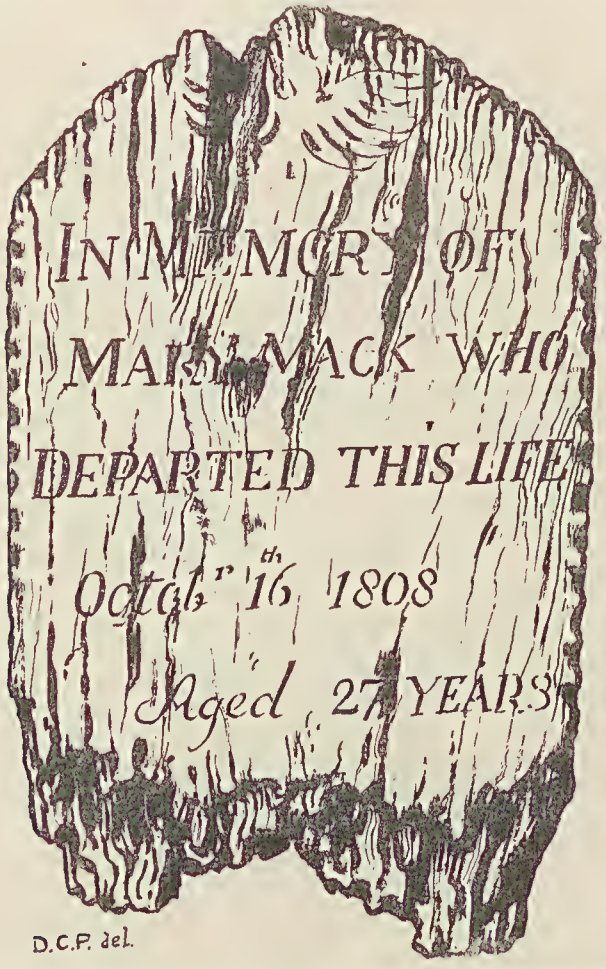
The following Sunday, 7th November, he rode to Clarence Plains and preached a funeral sermon on the death of his 'dear lamented girl'. 'Everybody' he added 'greatly affected by the Sermon'. On 10th November he baptised the new baby, giving her the name of 'Elizabeth Sarah Morrisby'. His many friends rallied round him and endeavoured to comfort him, but the old man never really recovered from his grievous loss, and from time to time we find entries which show his inability to forget. Thus, on 2nd June, 1831, he wrote 'This day I entered into my 69th year [it was really his 70th] and never to my recollection spent a more unhappy day. The death of my dear and ever-regretted girl, late E. Morrisby, was always in my thoughts, recollecting the many happy days she was with me, and her friends, to commemorate it. I expected the Rev. Mr. Connelly and another. They did not come'.

On 30th August, the anniversary of Betsey's birthday he said 'I always, when in Hobart Town, had a large party to dine with me, and how very happy we always were on this day. But now she is keeping her birthday in a happier place, by the side of that God whom she always put her trust in'.

Mr. Morrisby married again, much to the old man's disgust, but later he became reconciled to the new couple, and they were very good to him, and looked after him when he went to live at Rokeby. He became greatly attached to the two children, and often had Robert to stay with him. He sent him to the Orphan School at Newtown to be educated, and took him to Reviews on the Domain and to other entertainments.

By his Will, made in 1836 Robert Knopwood left everything he had to the two children. He died on 18th September, 1838, at Kangaroo Point, at the age of 77.

And so, when we look at this old slab of Tasmanian hardwood, with its rudely carved lettering, let us remember the story behind it, and keep it as an enduring memorial of a youthful romance, and of the charity and kindliness of a man, whose frailties are too often remembered, while his virtues and good deeds are apt to be forgotten.



Mary Mack's Headstone, formerly in St. David's Cemetery, now in the Tasmanian Museum.

On the Formation and Disposal of a Collection

By

W. E. L. H. Crowther

With 1 Plate

An interest in the extinct Tasmanian race was aroused by the stories my father used to tell of his contacts with the natives and by the presence of several of their Crania in the back surgery at our home. It was strengthened one summer holiday by watching Mr. Westlake of the British Museum collect their stone implements from a reef on the foreshore at Oyster Cove.

The real incentive came however, when Professor R. J. A. Berry touched on physical Anthropology in his Anatomy lectures at the University of Melbourne. He appealed then to his 3rd. year students for Crania and other skeletal remains of the Aboriginals to further an investigation he had undertaken. The need for Tasmanian material was particularly stressed and I was able to tell him of what was available at Hobart, Launceston, 'Kelvedon' and possibly Oyster Cove, where the last of the race had been buried. As a result, Dr. W. Robertson, his demonstrator in Anatomy, came to Hobart during the long vacation of 1908. He brought a Dioptograph with him and took tracings in four normae of Crania at the Tasmanian Museum, and Launceston. He also purchased the Crania at 'Kelvedon' for the University Museum. These had been collected early in the last century by Dr. J. F. Storey, Asst. Colonial Surgeon to the district of Waterloo Point (now Swansea). Our particular task was to investigate the old burial ground at Oyster Cove, situated in a small valley on my father's property close to the 'Station' where in 1847, the last of the Tasmanian Race were segregated after their removal from Flinders Island. To accomplish this Robertson stayed with a fellow student W. Inglis Clark at our cottage. Although the actual locality of the burial ground was well known to me, it was so heavily overgrown with scrub and bracken that a great deal of systematic digging had to be done before the first remains were unearthed. In all the skeletons of some twelve individuals were recovered and although matted and infiltrated by the rootlets of fern, the Crania were generally in fair preservation. The long bones had not fared so well and were so softened and distorted as to be of little anatomical value. At later periods the Cerebrum was found in two of the Crania. They were hard, dried and shrunken so as to resemble a small shrivelled apple. One handed to Professor R. J. A. Berry was described in much detail by G. Elliot-Smith (1911), the other, passed many years after to Professor F. Wood Jones at Melbourne, is yet to be done. The Crania were figured and described by Berry and Robertson (1909). Two were presented by my father to the Anatomy Museum, Melbourne, and one to Dr. Inglis Clark. The others remain in my collection.

In 1919 my association with the Tasmanian Museum and the Royal Society was resumed, and shorty after Mr. C. E. Lord suggested the examination of a number of aboriginal bones which had been discovered a year or two before at Eaglehawk Neck, Crowther and Lord (1920). Our interest then turned to their stone artifacts. The first locality examined was the Bluff at the northern end

of Opossum Bay, South Arm, where a number of implements were found. This midden was selected some years later, as the scene of the Habitat Group at the Tasmanian Museum and from it Capt. D. C. Pearse painted the imposing background. The search continued over the next fourteen years, on holidays and occasional week ends. Commencing in ploughed fields and fallow paddocks, at Rokeby, Carlton and South Arm, where odd implements only were exposed, experience led to more permanent camping grounds with a greater variety of remains. These sites were usually on the coast, close to bold promontories and reefs with fresh water nearby. Seaford at the mouth of the Little Swanport River was the most imposing. Here on its south bank are deposits of shells so enormous that they have long been used for lime burning. Implements are found among the shells but are more plentiful along the north bank as far as Lisdillon. They are found for the most part after the fields are ploughed, as erosion and sand blows are negligible in this locality. Later at the annual military camps at Mona Vale (Ross) several aboriginal camping sites at Grimes Lagoon and the Ross-Tunbridge area were examined and re-examined.

A mutual interest led to a long and happy association with the late R. W. Legge and visits were made with him to the coastal middens on the West Coast, from Mount Cameron West to South of Sandy Cape, as well as to the northern areas of the East Coast. Others who were actively collecting in Tasmania during this period were Dr. R. H. Pulleine, A. S. Kenyon and Dr. G. Horne from South Australia and Victoria. Messrs. Falkinder and Amos from Falmouth and Cranbrook, built up very representative collections of their areas of the East Coast. That of Mr. Amos, which included undescribed Crania, was bequeathed to the Tasmanian Museum but the untimely death of Mr. Falkinder left his undisposed of. The splendid collection made by Mr. and Mrs. Legge was presented to the Queen Victoria Museum, Launceston, and he was able to superintend its arrangement there before his death.

As a result of their activities a long and important series of studies on the extinct Tasmanian race have been published in this journal and elsewhere and also in the reports of the A. & N.Z.A.A.S. for which it was my privilege to act as Hon. Sec. of Section F (Anthropology) for the meetings of 1921 and 1934, as Vice President on several occasions and as President (Elect) of the Section at Adelaide in 1940. But unfortunately the outbreak of war led to its postponement. The invitation to act as President was renewed in 1946 but the long break and loss of touch with Anthropology did not seem to me to justify its acceptance. At these gatherings among many others Bishop Williams of New Zealand, Sir Hubert Murray, Dr. F. Wood Jones, G. Horne, J. B. Cleland, R. H. Pulleine and A. S. Kenyon were met, problems discussed and field work done.

A large collection of stone implements and other material had thus been acquired and towards the end of 1947 the question of its ultimate disposal became urgent. Mr. Legge had decided to give his material to the Launceston Museum and as there was an abundance of Tasmanian material at Hobart and very little at the federal capital, the collection was offered to the Institute of Anatomy, Canberra, on 12.9.1947. The gift was conditional that it should be kept as a whole under the name of my family and to be available in part for display and inspection, with the balance stored for research. The offer was accepted and Mr. R. P. Stone of the Institute came to Hobart to help with the marking of the specimens and their packing for transport. Each was marked T (for Tasmania) under that the locality where found and under that again C, to indicate it as part of the collection. There were three show cases and seven heavy store boxes of specimens.

No. 1 case contained well marked specimens from a number of localities, typical of the usual types from large hand axes and scrapers to pounding stones of coastal middens.

No. 2 case had specimens of all types from the Ross-Tunbridge area, Red Ochre and a group of bone implements from Seaford.

No. 3 case was limited to implements from the West Coast. Shells and bones from the usual types found on these coastal middens are included.

These three cases are now available for inspection in Canberra with the implements, in place as before transit. In addition a number of specimens which were considered to show interesting features in their working are displayed in show cases with appropriate legends, while another case contains a brief description of the Tasmanian Aborigines and their implements. The bulk of the collection remains in the store cases in which they were transferred and provides full material for future systematic study of the stone culture of the coastal and inland tribes of Tasmania.

The osteological portion of the collection, consisting of some 20 Crania and a limited number of long bones remains in Tasmania.

For the guidance of those who may wish to work over the principal areas from which these specimens were collected the following information is given.

The Coastal Middens of the East Shore

The coastal middens of the Aborigines are widely spread and may be found in almost any locality with a plentiful supply of shell fish and crustaceae and fresh water nearby. The principal sources of material have been the East Coast, the Northern third of the West Coast and the Estuary of the Derwent. The rich grounds of the North, from Woolnorth in the west through Port Sorell, Low Head and Bridport to the east are not represented. They have been systematically worked over by Wilkinson, Legge and others whose specimens are in the Launceston Museum. Localities represented range from Recherche Bay in the south through Oyster Cove, Nubeena (Roaring Beach and the large quarry near the summit of Mt. Communication), Wilmot Harbour, the better known sites at Rheban, Seaford, Lisdillon, Kelvedon, Swansea, Seymour, Falmouth and by the Bay of Fires almost to the extreme north of the East Coast.

The rudest of quartzite implements are characteristic of the South and South-East Coast and D'Entrecasteaux Channel. At Oyster Cove immediately in front of our cottage there is a small midden, made up of oyster and mussel shells. At low water some fifty feet from it are two outcrops of a hard yellowish to red igneous rock. These have been used as quarries and innumerable large flakes remain around them; none show secondary chipping, (I remember Mr. Westlake of the British Museum literally filling kerosene tins with them.) In the Tasmanian Museum there is one very well worked quartzite scraper, labelled as from Oyster Cove, the only such example I have seen, all the others are rough and primitive and typical of those found on the S.W. Coast and Port Davey. In the D'Entrecasteaux Channel area, dense forest came almost to high water mark. Here and on the S.W. Coast very little game was to be had and no specialised implements were needed to deal with foods taken from the sea.

It was very different on the northern side of the Derwent estuary. At Rokeby, Sandford, Lewisham and South Arm the types typical of the East Coast are fully developed and possibly the most specialised in the Island. Here the climate is warm and mild, the country lightly wooded and open, with large marsupials and birds to supplement the sea food. Some areas were constantly resorted to, especially during the winter migration to the coast. Seaford is such a place and was described over half a century ago by A. J. Taylor (1894). Most of my East Coast specimens were taken from there or from South Arm, Rokeby, Sandford, and Kelvedon. Typical and well worked examples are shown in the large show case (No. 1). Many from South Arm, brought in by Mr. Padman, were turned up at his farm on the Ralphs Bay shore about three miles from its southern end.

Usually these eastern shore implements were struck from a chert, cream, yellow or blue gray to black in colour and with a heavy patina. Occasional examples in quartzite, crystal or petrified wood may be found. Many are well shaped, with careful secondary chipping and the best are unequalled in other areas. They range from large hand axes and scrapers to very small examples. Though occurring most freely in exposed and denuded sites as at Seymour and small sand blows on the shore many inland areas after ploughing are rich in well worked implements.

At Rokeby, Droughty and Ralphs Bay, many pounding stones were found. These large pebbles, sometimes several pounds in weight, are peculiar to the foreshores. They show burred edges and signs of wear and use on the flat surfaces. This may vary from slight pitting to a well marked concavity. They appear to have been used as a hammer and anvil to crush the harder shell fish. (Case 1.)

The Seaford and Lisdillon shore middens always gave good yields. They are on either side of the mouth of the Little Swanport River. At Seaford on its southern side there is a solid bed of large oyster shells extending over several acres. It is undisturbed except near the shore where for many years the shells have been taken and burned for lime. The edge of the workings show a face of oyster shells from two to eight feet deep with an occasional admixture of other shells and charcoal. The lime burners from time to time discover stone implements and even human remains among the shells. A Calvarium and some long bones found in this way are in the Tasmanian Museum. Although no cultivation was being done at the time of my visits, many good artefacts were exposed on the paddocks of the farm. Over the river and across the flats as far as Lisdillon River they are found in numbers after ploughing and less often on the surface of the lightly grassed runs. Some miles to the north on the main Swansea road is 'Kelvedon' the home of Mr. Tilney Cotton. The old homestead built by his family in 1832 is still in use, where the Quakers, Messrs. Backhouse and Walker stayed during their visits to Van Diemen's Land, Backhouse (1843). For many years Dr. G. Fordyce Storey made it his home when Asst. Colonial Surgeon to Waterloo Point and the Rocky Hills Probation Station. He was a Physician Naturalist of the old type, deeply interested in Botany and corresponded with and collected for Baron F. Von Mueller. At 'Kelvedon' his rooms are much as he left them. In the small dark office and dispensary on the ground floor his books and chemical apparatus may be seen as well as a small still and his long wellington boots and cloak. Up the narrow stairs is the little museum with shelves now nearly empty. At one time Tasmanian Crania, a fine collection of early Maori material, a herbarium, shells and other objects of local interest were displayed on them. The Maori collection came to him from his friend Dr. Downie of

H.M.S. Cormandel. It included one or more dried heads as well as very valuable wooden and stone weapons, and a log book of the early thirties describing the ship's cruise. These were sold early this century, the purchaser stating that they were to be presented to one of the larger museums of New Zealand. Inquiry in the Dominion gave no record of such transaction and apparently the buyer retained them. The Tasmanian crania as already stated were purchased for the University of Melbourne.

'Kelvedon' lies by a small freshwater lagoon and creek and within a few hundred yards of the sea. It has been an ideal camping ground for the natives and every year splendid examples of their implements are turned up in cultivation. Each generation of the Cotton family have sent outstanding examples of artefacts to the Tasmanian Museum and have been most generous and helpful to those genuinely interested in such research. Specimens from 'Kelvedon' are generally of fine workmanship and moderate in size although large examples are found. The natives obtained them from an outcrop of stone extending over perhaps half an acre on one of the paddocks or from a similar source at 'Mayfield' five miles away. They are of a yellow to cream and blue chert with a heavy patina and very similar to those of the Midland areas, their finish is more than comparable to the best on this coast. Mr. Cotton, who told me of the stone quarries, believed the annual migration of aborigines from the midlands to the coast was by way of Swanston and the Eastern Marshes. This is the easiest way with plenty of game and with only some twelve miles of rough country between Swanston and Little Swanport.

Although Swansea and the Schoutens would be thought to offer much, little has been found in their vicinity. Mr. Legge and others have worked the coast from Mt. Murray and the ocean side of Sleepy and Wineglass Bay with disappointing results. Dr. Pulleine, Mr. Lord and myself in 1925 at a Field Naturalists camp on Schouten Island, found a midden as its western shore opposite Black Reef. It covered an extended area and on it were many implements of local stone and very crudely worked split pebbles from the beach. Very few traces of mainland stone were seen although one finely worked implement of that material was found near one camp. It had probably been brought by the natives by way of Schouten Main and the passage, to the Island.

In 1931 visits were made with Mr. Legge to Falmouth, Anson's Bay and Seymour. 'Cullenswood' his home, was centrally placed for such a purpose. He and Mrs. Legge had collected systematically at Long Point (Seymour) and their collection is rich in material from this site. The point itself is a flat exposed promontory with adjacent reefs and erosion has uncovered the middens. The specimens are of brown and black chert, medium to small with secondary working. It was here that Mrs. Legge found the first examples of microliths, Legge (1928). Falmouth has yielded some fair examples of worked implements. Mr. Falkinder who lived there, had become interested through his contacts with Mr. Legge and although hindered by bad health, by collecting on the east coast and exchange had formed a most interesting collection of Tasmanian and Australian material. Anson's Bay and Bay of Fires were visited on two occasions. There is a large site on the south side of the Anson's Bay River where it crosses the bar to the sea. It is windswept and eroded and covers rather more than an acre. The mounds are mostly composed of oyster shells. Stone implements were scarce but the few found showed good secondary working. On the second visit our objectives were the Bay of Fires and Eddystone Lighthouse. No middens were seen but the

search was cursory as time was very limited. On an earlier visit to the Musselroe River to study the large Forester kangaroo, no signs of aboriginal occupation were seen.

Human Remains.—Mention has been made of the important discovery at Eaglehawk Neck. A partially incinerated skeleton found at Pipe Clay Lagoon by Mr. A. Morrisby has been described by the writer (1933).

The Crania in the Amos Collection, also one from South Arm and another from Carlton are in the Tasmanian Museum and are not yet described.

Ross-Tunbridge Area

The large central Midland plain continues to the north for many miles from the divide at St. Peter's Pass; through Tunbridge, Ross, Campbell Town and Conara and as Norfolk plains eventually reaches the shores of Bass Strait and Port Sorell. The plains with their extensions to the north west and east, have always been open and lightly wooded and well watered by the Blackman, Macquarie, Elizabeth and South Esk rivers as well as having occasional small lakes, lagoons and marshes. It is thus ideal country for small tribes and groups of hunters with their families.

Occasional stone implements are found in many places and in numbers on their semi-permanent camping grounds. It has been a classic ground for investigators. Scott described the remains at Glen Morrison (Scott, 1875) and since then, Noetling, Pulleinè, Legge, Kenyon and many others have worked over the sites. My own association with the area was usually when on military duty at the annual encampments at Mona Vale (Ross). The camp may be reached by a dirt road from Tunbridge, which follows the foot hills for some miles past Ballochymle, and the shore of Grimes Lagoon. The country here is lightly grassed with a red sandy soil and easily eroded. The road either skirts or passes over many small sand blows and many rejects and worked stones remain on the hard clay 'pan'. Year by year they were examined, at first on foot at the end of the day's duty, or, when more distant, by horse or car. The search was extended eventually as far as Glen Morriston and Glen Morey. Every patch of erosion showed some evidence of occupation but implements were most plentiful by the shore of Grimes Lagoon and on the slopes of the low foothills that lead away towards the Eastern Tiers. The finest examples were found one very dry season on the bed of the Lagoon. No outcrop of stone was seen, but Noetling (1908) has described a large quarry at Syndal, only a few miles away. The material used was occasionally carried to the camp sites in bulk, as large cores or nuclei from which implements have been struck have been found on them. Two of yellow chert, the principal material used, are in the collection; varieties of bluish grey chert and black shale also occur. Implements of petrified wood, quartzite and rock crystal are rare.

Some three miles further east, from the southern end of the lagoon a fine camp was exposed. It lay on a lightly wooded foothill and was typical of several others in that it had spread from the craters left by dead and uprooted gum trees. The fine red surface soil was one to three feet deep at its periphery and large numbers of used implements, including a large core lay on the clay subsoil. There were also a group of well worked hand axes, larger than any others seen in the district, and many utility scrapers, of medium size. Many chips showed that implements had been worked up on the spot. These examples are shown in Case 2.

Between the lagoon and foothills were the other small sites. One seemed to have been used specifically for the shaping and finishing of small to medium scrapers. Two small heaps of chips were removed and are shown in the same case. While most are simply flakes, a limited number are shaped and show secondary working on the edges, and may be classed as microliths. On another patch a mile or so away were only a few implements with a number of pieces of red ochre. One small block showed fine striations as if it had been rubbed directly on the face and beard. The largest piece was deeply pitted and showed coarse scraping. Smaller fragments were untouched. On a nearby site, a large rock pebble with a shallow concavity extending over all its upper surface, was found. There was no staining to establish its use as an ochre mill. On New Year's Eve of 1927 my wife and I noticed a 'blow' from the Main Road at Conara, and a walk of about four miles across the back runs of 'Winton' brought us to it. The site extending over an acre was on the slope of a low hill above a soak or small marsh. The implements on it were numerous but of no particular interest. Many small pieces of ochre were collected, none showing evidence of scraping or application. All these are in Case 2.

No human remains have been found in the Midlands for many years. The cremation of their dead seems to have been an invariable procedure as ample dry wood was always at hand for that purpose. No caves were seen but it is still possible that finds of aboriginal bones comparable to that of Pulleine (1924) near Cornwall may be made. Further afield a visit was made to the Lagoon by Ellinthorpe Hall, but only a few implements were found around its shore. White Lagoon just off the main road near Tunbridge was no better.

The Western Shore

Following in the steps of Dr. R. H. Pulleine, who for four years had spent his holidays in the Sandy Cape area of the West Coast, Mr. Legge and myself made two visits in 1927 and 1934. On each occasion Marrawah was our headquarters and we worked from Mr. Cameron West in the north to four miles south of the Cape, in all some 40 miles. At Mount Cameron West the very interesting rock carvings discovered by Meston (1934) are situated among the extensive shell mounds and in a good country for game. To the south lie Green Point, West Point, Temma, The Bluff (Whale Head), Ordnance Point and Sandy Cape. On each of these promontories are the remains of permanent or semi-permanent habitations of the natives. Between them are the long broad sandy beaches so typical of this part of the coast, often miles in length and up to half a mile in depth, following erosion of the wooded sandhills of the foreshore. The beaches are intersected by streams ranging from the Arthur River, a broad swift stream crossed by a punt, to insignificant creeks. The smaller streams such as the Pedder and Sunrise disappear into the sand and form quicksands which have to be avoided. Behind the beaches are broad coastal plains covered with a heathy scrub and stunted eucalypts. Some miles inland the plains rise to the Norfolk Range which is heavily wooded. Travelling is easy as the stock follow the plain close to the sea and have left a sandy track. In several areas the cattle graze under a system of agistment. Their advent has been followed by erosion of the sand hummocks. As a result in place of a dense scrub sufficiently compact to give the natives full shelter from the wind and rain, only the subsoil remains and in many places this is strewn with stone implements and the shells and bones of their hearths. Such remains are found in many places

along the coast and the most extensive are on the promontories already named, where ample shell fish were to be had from the adjacent reefs. Even to-day on the larger hearths shells and bones are found matted together by the grease and charcoal of the fires (fig. 2). It was from this area G. A. Robinson removed the last free aboriginals and it has an interest and fascination of its own. Indeed the sense of the past is immediate and overwhelming. Time did not allow us to go more than few miles south of Sandy Cape, but it is probable that middens continue to the Pieman River and the entrance of Macquarie Harbour. Implements and rock carvings from Trial Harbour have been described by J. F. Jones (1937).

Further south from Cape Sorell to the entrance of D'Entrecasteaux Channel, the coast is bold, forbidding and exposed and Mr. Lord after visits to Port Davey and the South Coast brought back only the crudest of stone implements.

In 1927 we started from Marrawah where we had hired three horses and a chaise cart with Mr. G. Cartledge as driver. West Point which is of hard quartzite and bounded by small sandy beaches to the north was examined first. Extensive shell remains and numerous implements were found in its vicinity. The next stage was a stretch of some 27 miles and that portion of it from the Arthur River to Temma was the most interesting. Broad beaches extend all the way and behind them sand blows started by the cattle. Such eroded sites extended over acres of ground, and on them were innumerable stone implements and such shells as haliotis, green whelks, mussels and occasionally oysters recovered from reefs and sandbanks off shore. The well watered plains just inland then afforded game and wildfowl to supplement their diet and occasionally the shore yielded stranded seals or whales. Temma is a partially sheltered inlet from which steamers landed heavy machinery for the Mount Balfour mines but now only a small weatherboard hotel remains.

From Temma we worked southwards towards Sandy Cape. The track ran parallel to the sea as far as Ordnance Point which is an outstanding example of a well used camping site with the hearths almost as they had been when abandoned a century before. The long curving arc of the beach, lashed by a hard westerly gale, was followed for some miles to the turnoff through the tea tree scrub at Sandy Cape. The tea tree here is in its original state (Fig. 1) and was an ideal shelter for the scattered groups of native families inhabiting the locality. Mr. Ford of Marrawah informed Mr. Legge that, forty-five years before, the dunes and flats south of the Arthur River now bare and eroded had been covered by such dense thick scrub almost to high water mark.

At Sandy Cape the hut was about twelve by fifteen feet and contained a fireplace, bench table and built in bunks and running water a few chains away, here we spent two most interesting days. The birds, especially the grass parakeets, were plentiful as were snakes. Wild duck and kangaroo helped out our supplies. The peninsula of the Cape was open savannah, well grassed and interspersed with clumps of tall tea tree very like Mornington Peninsula at Port Phillip. The promontory itself is of granite and on the foreshore are many shell mounds and implements. Here I found the splendid pounder of granite now displayed in Case 3. A visit to Sea Devil Creek some miles further south took us to other middens of the same kind.

On the return to Marrawah some hours were spent at Ordnance Point and a fruitful day among the middens at Temma.

A second visit to Marrawah was made in 1934 principally to examine the rock carvings at Mount Cameron West and the camp site at the Bluff. Dr. Pulleine (1928) considered this area to show undoubted signs of permanent habitation. Our impression was that the midden sites were not as distinctive or permanent in type as he described. Shell remains with bones of cetaceae and seals were abundant but not more so than at Ordnance Point (fig. 2). The next day we rode to Mount Cameron West leaving the horses at the V.D.L. Co's boundary and a walk by the track past the stockyards to the Coast. Here by the shore are the rock carvings discovered by Meston. They have been exposed to the drift of sand and are covered in part or not according to the strength and direction of the winds. The rock face is dry and friable and crumbles easily. Sixteen years ago the matter of their preservation was a matter of urgency but nothing has yet been done. The following day was spent at West Point but nothing of note was found.

It will be realised that camping sites along the Northern third of the West Coast are numerous and of great interest. At the Bluff, Sandy Cape and Ordnance Point there is evidence of permanent or semi-permanent occupation. The stone implements are distinctive and struck from quartzite and in some instances a black shaleite. No outcrops of quartzite were seen but Dr. Inglis Clark stated he had known them in the Mount Balfour area. Long exposure to wind and sun on the beaches had given the implements a very distinctive colouring usually cream to milky blue. The patina is not marked as the colour seems as if it had been 'fired' on the stone. Some specimens were almost opalescent. In all the many hundreds of implements handled perhaps one in a thousand showed secondary chipping. No specialisation of type occurred among the cutting tools, they are simply flakes of various sizes and any shade with a cutting edge. It is different with the pounders. They are very numerous, of several sizes and weigh from an ounce or two, to as much as six pounds. Much use has been made of pebbles of small to medium size, which show uniform wear of unusual type all around their periphery. These have been described by R. W. Legge (1927). Case 3 contains examples of all types, taken at random from the sites mentioned.

Human Remains.—Within this century the great proportion of discoveries of aboriginal remains have been made in the N.W. Area of the Island, usually by those planting Marram grass to prevent extension of the sand blows. One such Cranium, offered to me was worthless as most of the outer table of bones had fretted and weathered away. A number of skulls in better preservation have been acquired by collectors and institutions. Mrs. Legge on one visit found the cranium of an infant, in excellent preservation. This she presented to the Tasmanian Museum. Such discoveries have made it clear that cremation of the dead was by no means the universal practice of the tribes of this locality.

Conclusion

An attempt has been made to co-ordinate the names of localities inscribed on specimens of the collection with the topography of the camps and areas examined, as an aid to those who wish to examine the sites. Detailed description of types of implements and the material from which they were struck as well as other data relating to the extinct Tasmanians may be found in a long series of articles in the P. & P. R. Society of Tasmania. See Register of Papers, 1841-1885, Part I, Register of Papers, Part II, 1886-1944; and subject index of papers of

Royal Society of Tasmania, 1898-1944. Perhaps the most valuable summary and descriptions of the stone culture of the Tasmanians and especially of the West Coast Tribes will be found in the Presidential address of Dr. R. H. Pulleine, Section F of the Australian Association for the Advancement of Science, Hobart Meeting, 1928.

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PLATE I

Fig. 1.—Tea Tree Scrub at Sandy Cape, Tasmania.

Fig. 2.—Shell Mound at Sandy Cape, Tasmania.

Fig. 1

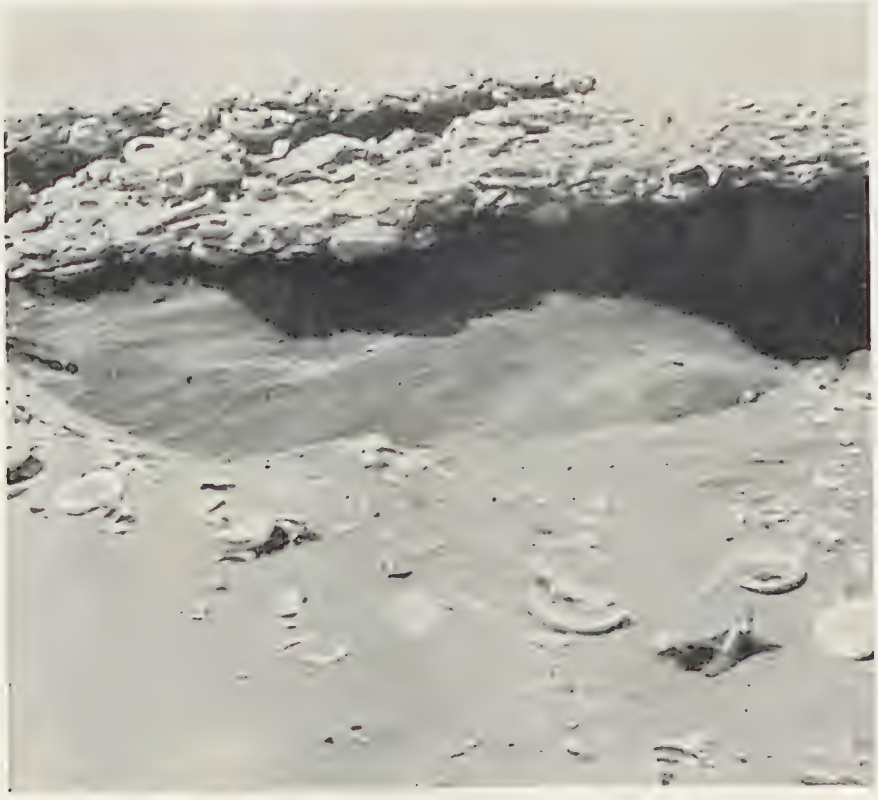

Fig. 2

Pap. & Proc. Roy. Soc. Tasmania, 1949 (15th September, 1950)

A study of the Tasmanian Psocoptera with Descriptions of New Species

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(With 117 Text Figures)

Prior to the work of Hickman (1934), only isolated references to the Tasmanian members of the Psocoptera appear in the literature. Enderlein (1903, pp. 407-8) describes *Ectopsocus froggatti* from Tasmania. Tillyard (1923) records the presence of *Myopsocus australis* in Tasmania. Badonnel (1943, pp. 149-151) has revised the taxonomy of two species previously described by Hickman.

The present paper deals with 13 species and includes seven new ones and two new varieties. A redescription of six species has been found necessary owing to the incomplete nature of the existing descriptions. An interesting new genus, *Interpsocus*, possessing some of the characters of *Peripsocus* Hagen and of *Ectopsocus* MacLachlan, is described.

Specimens collected are from the east, south-east and north-west areas of Tasmania.

The method of classification of the order by Pearman (1936) has been adopted in this work.

The symbols used in all descriptions of wings in this paper are those used by Badonnel (1943) and are similar to those used by Enderlein (1903); they are shown in fig. 1 while the scales employed in nearly all diagrams are shown in figs 1-3.

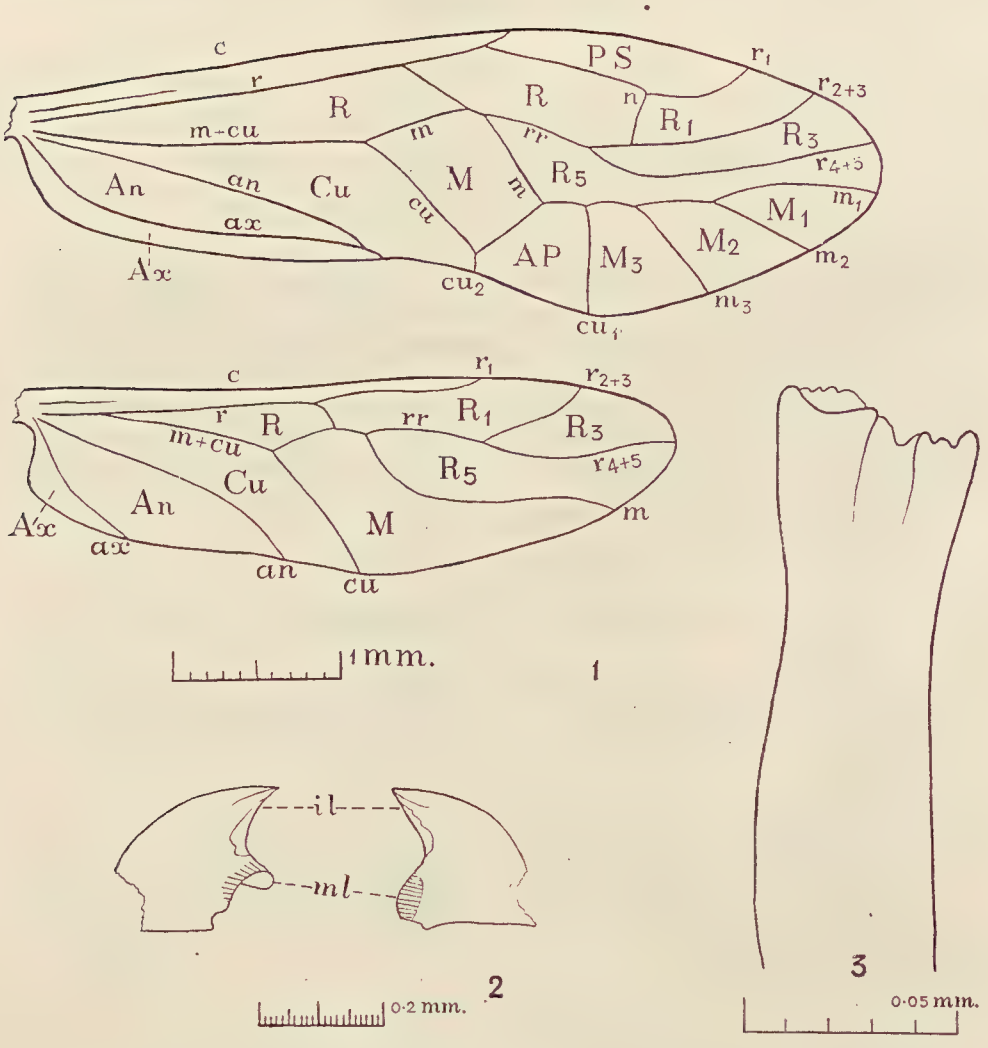
Fig. 1—Wings.
Fig. 2—Gonapophyses, subgenital plates, hypandria, paraprocts.
Fig. 3—Lacinia, claws.

Where the scales are not applicable, a separate indication of size is given.

All measurements of the length of the body are taken from specimens preserved in 90 per cent alcohol.

Key to Families

1.	Tarsi with two segments; antennae with 13 segments	2
	Tarsi with three segments in adult insect	5
2.	Forewing with areola postica (A.P.) free or joined to the media	3
	Forewing without A.P.	*Peripsocidae*
3.	A.P. joined at its apex to the media	*Psocidae*
	A.P. free	4
4.	Posterior border of hindwings with alternate long and short hairs	*Trichopsocidae*
	Posterior border of hindwings without alternate long and short hairs	*Caeciliidae*
5.	Apex of A.P. fused at a point with the media	*Myopsocidae*
	Apex entirely free	*Philotarsidae*



FIGS 1-3

Clematostigma tardipes n.sp. Fig. 1: wings (female) showing venation and cell nomenclature. Fig. 2: mandibles (female); *il*—incisor lobe; *ml*—molar lobe. Fig. 3: lacinia (female).

Group PSOCETAE Pearman

Family *PSOCIDAE*

Two segmented tarsi. Antennae with 13 segments. Wings hairless except for the margin of R3 in the hindwing in some genera; pterostigma thick and not joined to the radius by a transverse vein; areola postica joined to the media at its apex either for a short distance, at a point or, exceptionally, by a short transverse vein. In the hindwing *r* and *m* fused for a moderate distance. Claws with a tooth and with or without an empodium. Gonapophyses complete in the female. Hypandrium of the male may or may not be symmetrical, but is generally ornamented. Eggs deposited singly or in groups, covered by a rough encrustation or, exceptionally, by a web.

In defining the family Psocidae, Badonnel (1943, p. 31) states 'Griffes sans dents et sans empodium'. However, in describing *Psocus zambezianus* (1932*a*, p. 108) he mentions the claws as being strongly toothed. Moreover, Enderlein (1927, p. 3) describes the family as having 'Klauen gezähnt' and also (1903, pp. 225-6) states that toothed claws and an empodium are present in *Psocus circularis* Hagen and *Psocus quinquepunctatus* MacLachlan. Cope (1940, p. 109) figures the claws of *Psocus confraternus* Banks with a tooth, but states that the claws have no empodium (p. 96).

In the author's collection are three species belonging to this family and in each case the claws are toothed but there is no empodium. Badonnel's statement, therefore, appears to be incorrect and the family should be defined as having toothed claws with or without an empodium.

The family is divided into four sub-families as follows:—

1. Hypandrium of the male symmetrical; parameres free distally, never forming a closed complex:
   - *(a)* Hypandrium enclosing the eighth sternite .... *Amphigerontiinae* Badonnel
   - *(b)* Hypandrium limited to the ninth sternite .... *Clematostigmatinae* n. sub-fam.
2. Hypandrium asymmetrical, limited to the ninth sternite; parameres forming a completely closed complex:
   - *(a)* Larvae covered with glandular hairs .... *Psocinae* Pearman
   - *(b)* Larvae without glandular hairs .... *Cerastipsocinae* Pearman

Sub-family Clematostigmatinae n. sub-fam.

Hypandrium of the male symmetrical, limited to the ninth sternite. Parameres of male free distally, never forming a closed complex.

Genus **Clematostigma** Enderlein, 1906

Venation similar to that of *Psocus* Latr. except that there is a rudiment of a transverse vein at the posterior angle of the pterostigma. In the forewing *r* and *m* are fused for a moderate distance.

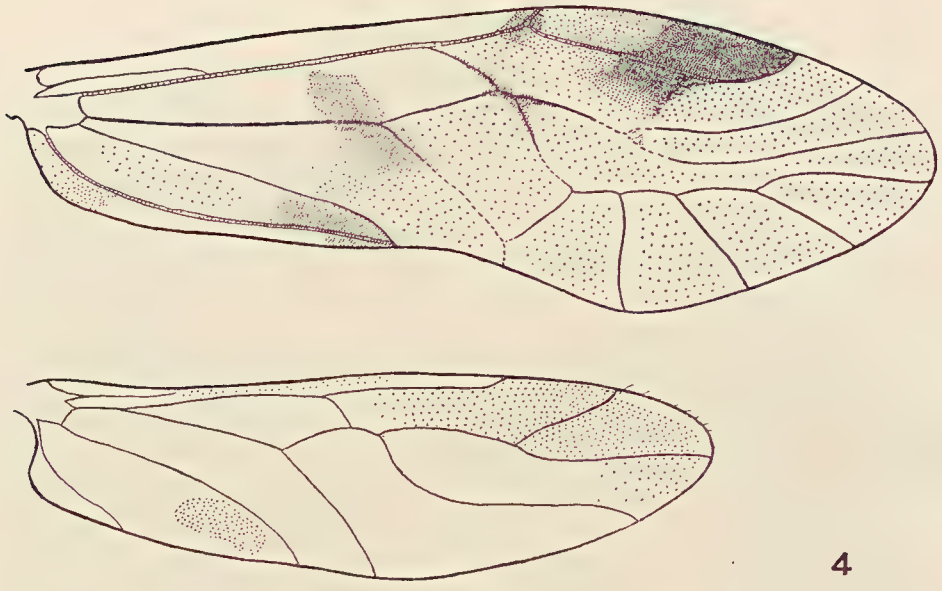
As the author has not seen the type species, *C. maculiceps* Enderlein, 1906, and it has not been fully described, it is impossible to give further characters.

Clematostigma tardipes n.sp.

(Figs 4-17)

FEMALE

Colour. Head white with black and brown markings; median epicranial suture edged with black from the middle to the posterior end; from each side of the suture two dotted black lines pass along the posterior border of the epicranial



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5

FIGS 4-5

Clematostigma tardipes n.sp. Fig. 4: wings (female). Fig. 5: wings (male).

plates to the eyes; a series of black dots present around the eyes; frons with a median black circular area, its apex at the median ocellus; clypeus white with median vertical black lines and an anterior white edge; anteclypeus grey; labrum grey with median brown patches; distal end of labium dark brown, proximal end white; jaws white with a brown area below the eyes; ocelli pale yellowish-green, each ocellus encircled by a dark brown ring; maxillary palps with the first, the second and the proximal half of the third segment pale brown and with the distal half of the third segment and the fourth segment dark brown; antennae with the basal halves of the first two segments black, distal halves grey, the third segment reddish-brown and the distal segments dark brown.

Prothorax brown with white lateral edges; mesothorax black with median pale yellowish-green areas in the antedorsum and between the antedorsum and the lateral dorsa; metathorax black with a median pale yellowish-green area in the antedorsum. First leg: coxa pale brown; trochanter pale brown; distal end of femur dark brown, remainder pale brown; tibia light brown with dark brown ends; tarsi and claws dark brown. Second and third legs similar to the first leg except for the dark brown coxae.

Wings (fig. 4) with distal cells pale brown. Forewing with a brown area in the proximal portion of Ax; a dark brown area at the top distal end of R merges into light brown in the middle and again into dark brown in An; pterostigma pale brown with dark brown ends; pigmented area of the pterostigma passing nearly to the fork of *rr* with the distal edge pale yellow; veins dark brown except for the pale brown veins *c*, *r*, *an*, *cu*, *cu2*, part of *m* and the fork of *rr*; membrane with red to green iridescence. Hindwing with a pale brown area in the distal end of An; veins brown except for the paler veins *ax*, *an*, *r* and *r1*; membrane with red iridescence.

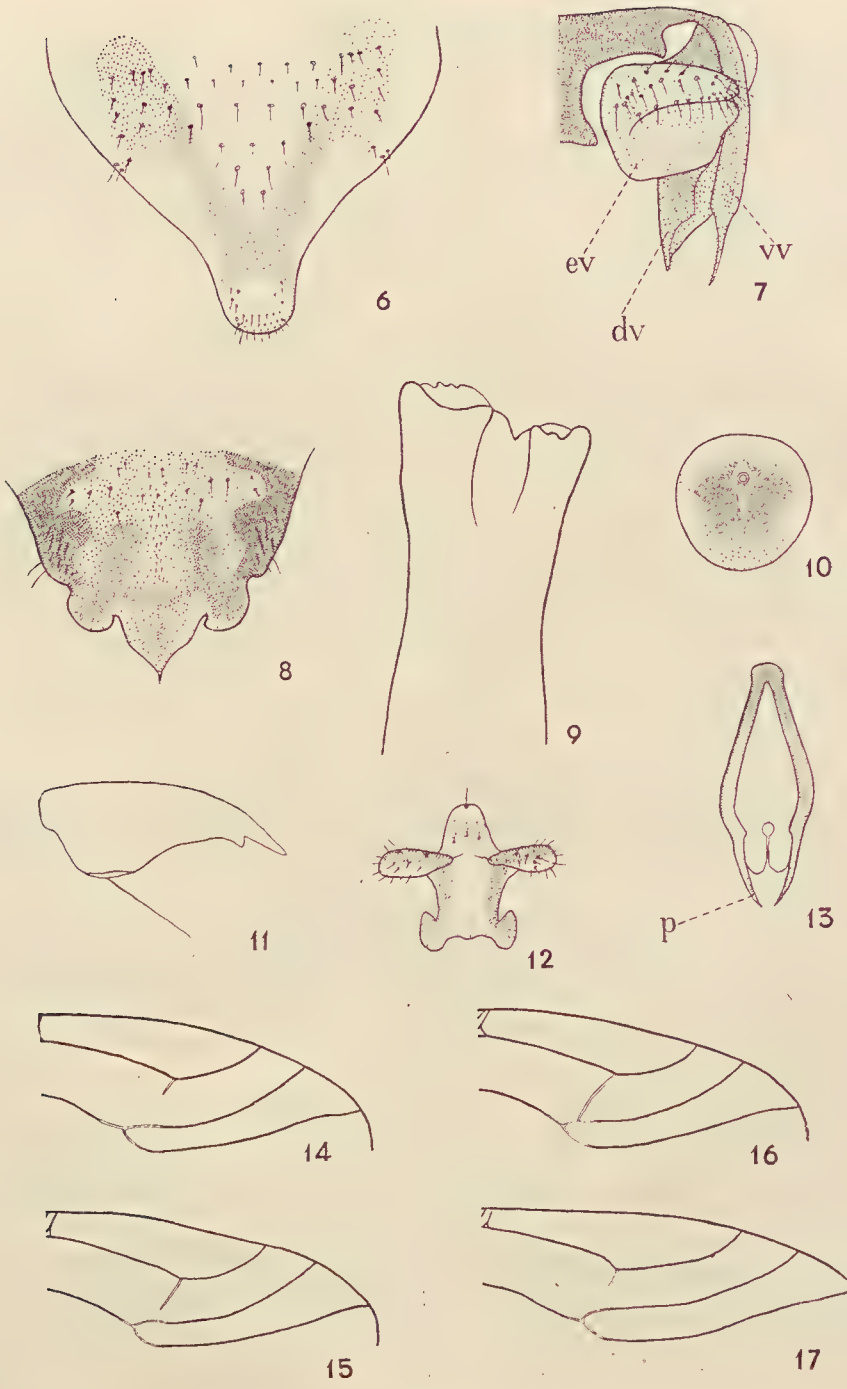
Dorsal surface of abdomen white with black markings; ventral surface white; some specimens with a greenish-yellow tinge to the abdomen; apex of abdomen dark brown; external surfaces of gonapophyses dark brown, internal surfaces pale brown.

Morphology. Head sub-triangular in front view, semi-circular in side view; median epicranial suture distinct; clypeus large and bulging; ocelli three, slightly separated; eyes small, protruding, interspace three times apparent eye diameter; lacinia (fig. 9) with two large teeth; mandibles normal; maxillary palps long and hairy with the distal segment slightly oval; antennae long with short hairs. Head covered with short hairs.

Prothorax small, hairless and almost hidden; mesothorax with a few short scattered hairs, metathorax hairless. Legs hairy; tibia with two apical spurs; claws (fig. 11) with a preapical tooth and a stiff basal bristle; ratio of tarsal segments of the third leg 2 : 1; first segment of posterior tarsus carrying 25 hairs with pectinate bases, the second segment without pectinate hairs.

Abdomen large and oval; epiproct large and rectangular; subgenital plate (fig. 6) with a single median lobe; opening of spermatheca (fig. 10) rounded. Gonapophyses (fig. 7): ventral valves dilated preapically and terminating in a long sharp point; dorsal valves with a large fleshy lobe and an acute apex; external valves bilobed transversely.

Length of body, 3·9-4·5 mm.
Length of forewing, 4·8 mm.
Length of antennae, 4·1 mm.



FIGS 6-17

Clematostigma tardipes n.sp. Fig. 6: subgenital plate (female). Fig. 7: gonapophyses (female), *ev*—external valve; *dv*—dorsal valve; *vv*—ventral valve. Fig. 9: lacinia (female). Fig. 10: opening of spermatheca (female). Fig. 11: claw (female). Fig. 12: epiproct (male). Fig. 13: penial complex (male); *p*—paramere. Figs 14-17: positions of stump vein from the base of the pterostigma.

MALE

Colour. Slightly darker than the female especially in the abdomen; thorax similar to that of the female except for pale yellowish-green lateral edges of the prothorax; abdomen pale yellowish-green with black markings on the dorsal surface.

Forewing (fig. 5) hyaline; pterostigma dark brown; distal ends of anterior cell, cell R1 and apical cells pale brown. Hindwing (fig. 5) hyaline; distal cells pale brown.

Hypandrium (fig. 8) brown.

Morphology. Head noticeably smaller than in the female; eyes large and prominent, interspace twice apparent eye diameter; antennae long with thick, moderately long hairs; wings longer than in the female.

Abdomen thin and slender with the posterior end curved upwards; epiproct (fig. 12) trilobed in front and with two small lobes behind; paraprocts with three small lobes.

Hypandrium (fig. 8) symmetrical and trilobed, the median lobe ending in a sharp point. Penial complex (fig. 13): parameres reunited anteriorly by a membranous lamina but free apically.

Length of body, 2·5 mm.
Length of forewing, 5·3 mm.
Length of antennae, 4·9 mm.

The stump vein in the forewing was not present in all the specimens collected. When present in the female the degree of development varied. The following variations occurred:—

Stump vein absent, 7 males, 5 females.
Stump vein very short (figs 14, 17), 4 males, 7 females.
Stump vein passing halfway to $r2 + 3$ (fig. 15), 4 females.
Stump vein meeting $r2 + 3$ (fig. 16), 1 female.

Habits. Most specimens have been found on the leaves and branches of *Pittosporum* spp.; one specimen was obtained from rolled *Eucalyptus* bark and several from the leaves of *Beyeria viscosa*. When disturbed the insects move very sluggishly in contrast to most other Psocids, which move quickly.

Locality. Type specimens collected Hobart, May 8, 1949, 1 male, 1 female; Hobart, May 8, 1949, 7 males, 9 females, 3 nymphs; June 7, 1949, 1 female; July 2, 1949, 3 males, 6 females, 1 nymph.

Types. Holotype (female) and allotype (male) in the Australian Museum, Sydney.

This species closely resembles *C. maculiceps* Enderlein, but differs from it in size and in the colouring of some parts of the body.

Family MYOPSOCIDAE

Adults with three segmented tarsi. Antennae with 13 segments. Forewings: venation similar to that of the family Psocidae; entirely glabrous or with short hairs; pigmentation generally in the form of numerous irregular and confluent brown areas. Larvae with glandular hairs. Eggs laid in groups and covered by a rough encrustation.

Key to Genera

Female genitalia:

External valves rounded (fig. 23) .... *Myopsocus*
External valves triangular (fig. 39) .... *Pentacladus*
External valves rectangular (fig. 59) .... *Tricladellus*

Genus **Myopsocus** Hagen, 1866

Forewing strongly pigmented, the colouring resembling that of certain lichens. Venation like that of *Psocus*. *r* and *m* fused for a moderate distance in the hindwing, but in the forewing this distance is very short and often reduced to a point.

From a consideration of the characters of the two redescribed species, it is proposed to add the following generic characters:—

Hypandrium of the male bilobed and very heavily chitinised; parameres free apically and with a median chitinised plate. Subgenital plate of female with a single median lobe; gonapophyses with reduced ventral valves, long and strongly chitinised dorsal valves and rounded external valves.

Myopsocus australis (Brauer, 1866)

Psocus australis Brauer, 1866.

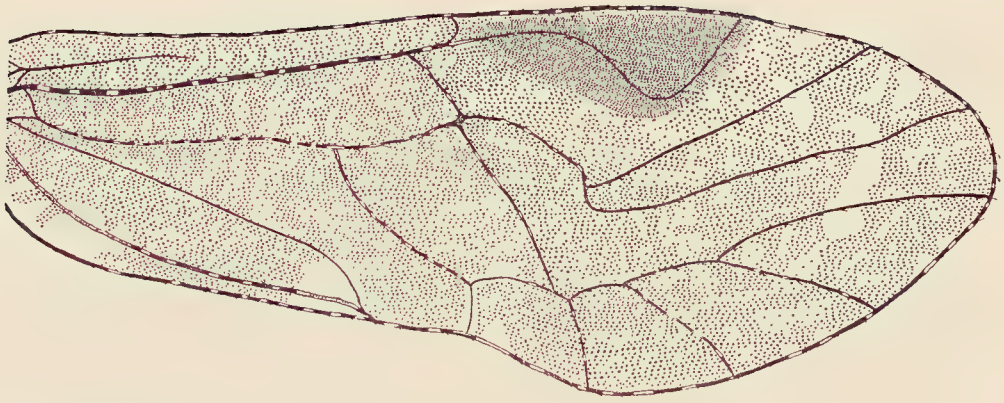
(Figs 18-25)

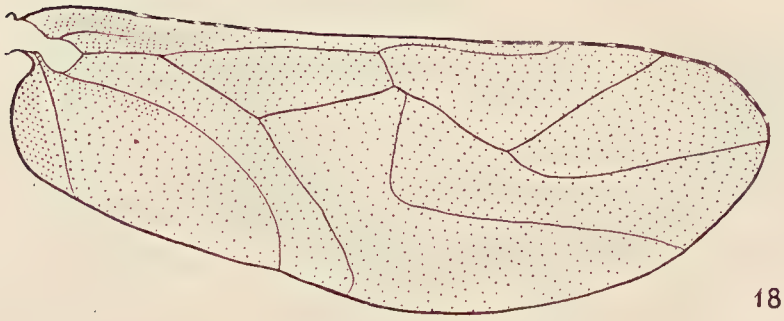
FEMALE

Colour. Epicranial plates yellowish-white with brown lines; median epicranial suture brown; frons brown; clypeus pale yellow with vertical brown lines and with anterior edge pale reddish-brown; anteclypeus pale brown; labrum pale brown, the anterior edge being darker; proximal portion of labium grey, distal portion pale brown; jaws white except for a brown area just below the base of the antennae; ocellary tubercle dark brown with pale grey between the ocelli; ocelli pale bluish-grey; eyes dark grey; maxillary palps pale brown except for the dark brown distal half of the fourth segment. First and second segments of antennae pale brown, proximal portions of the third and fourth segments testaceous, distal portions brown; remaining segments dark brown.

Prothorax pale brown. Mesothorax: antedorsum brown with pale brown posterior edges and a median pale yellow line; lateral dorsa brown with pale yellow median and lateral edges; scutellum brown. Methathorax: antedorsum and scutellum pale brown; lateral dorsa pale yellowish-brown with testaceous edges. Legs: coxa pale brown; trochanter white; femur white with brown ends; tibia testaceous with the distal extremity dark brown; proximal half of first tarsal segment testaceous, distal half, together with the second and third tarsal segments and the claws, dark brown.

Forewing (fig. 18) pale grey mottled with brown; very pale areas present in cells R1, R3, R5, An and Ax and also in the areola postica; pterostigma dark reddish-brown, the pigmentation extending slightly below the posterior boundary; most of the veins with alternate brown and yellow sections, the exceptions being *r2 + 3*, *r4 + 5*, *m1* and *cu2*, which are brown, and the reddish-brown vein *an*; membrane with gold to green iridescence. Hindwing (fig. 18) pale brown with darker areas in the costal cell, cells An and Ax and in the apical portion of the distal cells; veins pale brown proximally, becoming darker towards the wing apex; margin of the wing near the apex with alternate brown and yellow markings, the remainder being brown; membrane with red to gold iridescence.





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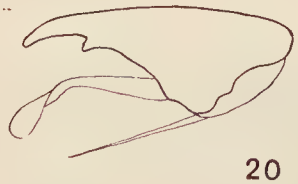

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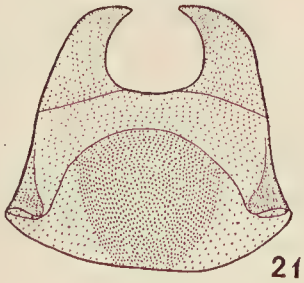

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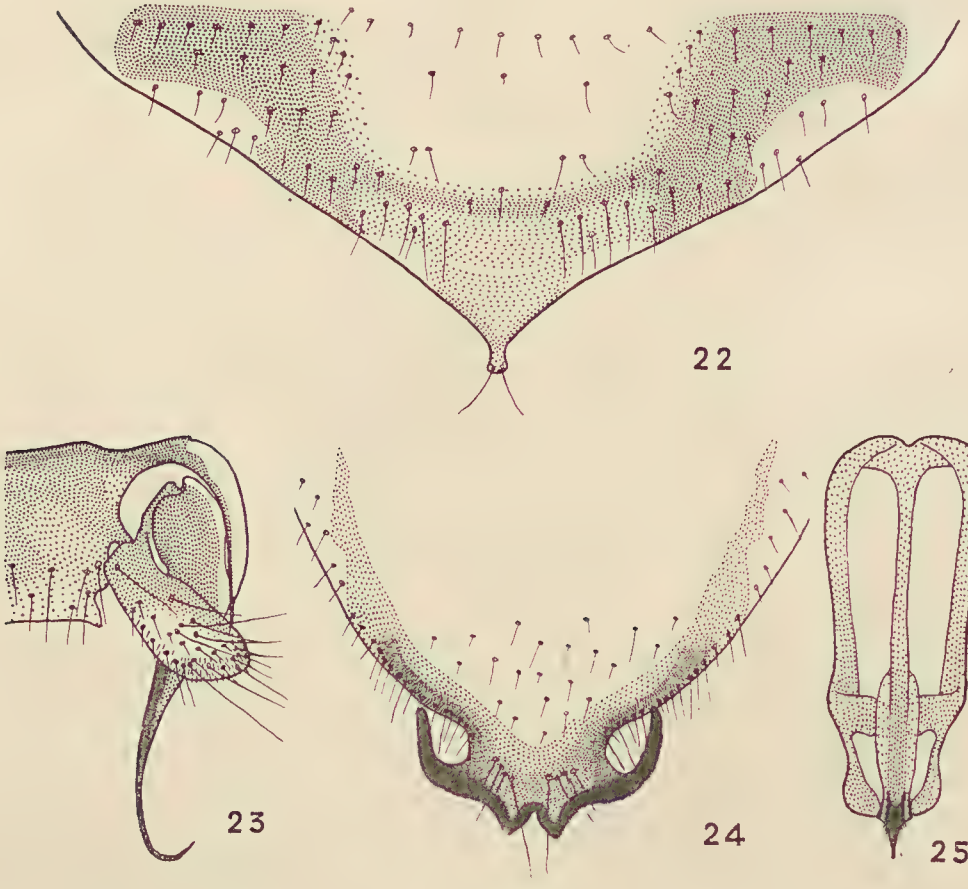
FIGS 18-21

Myopsocus australis (Brauer). Fig. 18: wings (female). Fig. 19: lacinia (female). Fig. 20: claw (female). Fig. 21: epiproct (male).

Dorsal surface of abdomen pale yellow with reddish-brown bands on each segment; ventral surface cream with a few brown areas; apex of abdomen pale brown with the exception of the dorsal valves and the sensory plates, which are nearly black.

Morphology. Head large, sub-rectangular in front view, semicircular in side view with the dorsal posterior edge rounded; median epicranial suture distinct; clypeus large and protruding; ocelli three, close together; eyes of moderate size, interspace two-and-a-half times apparent eye diameter; lacinia (fig. 19) possessing two unequal teeth, the larger one with many small teeth; mandibles normal; maxillary palps long and hairy, the distal segment slightly rounded; antennae long, possessing short hairs; head, except the jaws, covered with short hairs.



FIGS 22-25

Myopsocus australis (Brauer). Fig. 22: subgenital plate (female). Fig. 23: gonapophyses (female). Fig. 24: hypandrium (male). Fig. 25: penial complex (male).

Prothorax small, hairless and almost hidden; mesothorax with short hairs, metathorax hairless. Legs hairy; tibia with two apical spurs; ratio of tarsal segments of the third leg 4 : 1 : 1; first tarsal segment of the third leg having 21 hairs with pectinate bases, other tarsal segments with one such hair; claws (fig. 20) with a preapical tooth, a well developed pulvillus and a basal bristle.

Wings (fig. 18) large; membranes minutely punctate; greatest width one-third length. Forewing with minute hairs on the wing margin and all the veins except *an.* Hindwing hairless.

Abdomen large and oval; epiproct large and semicircular; subgenital plate (fig. 22) with a single median lobe carrying two long hairs. Gonapophyses (fig. 23): ventral valves reduced; dorsal valves long, strongly chitinised and with an acute apex; external valves rounded.

Length of body, 4·4-4·8 mm.
Length of forewing, 5·0-5·5 mm.
Length of antennae, 4·8 mm.

MALE

Colour. Brown markings on the head much darker than in the female; a brown patch present around the median epicranial suture; first three segments of maxillary palps pale brown, distal segment dark brown. First two segments of antennae pale brown, proximal half of the third segment testaceous, distal half dark brown; distal segments dark brown.

Yellow areas on the thorax smaller than in the female. Legs darker. Wings with larger grey areas than in the female.

Abdomen: dorsal surface white with brown bands on each segment; ventral surface white; end of abdomen, except for the dark brown hypandrium, pale brown.

Morphology. Head small; ocellary tubercle prominent; eyes large, interspace one-and-a-half times apparent eye diameter; antennae smaller than those of the female, but with longer hairs.

Body small, the abdomen curved upwards posteriorly. Wings smaller than in the female. Epiproct (fig. 21) large and rectangular with a lateral projection from each side passing backwards. Hypandrium (fig. 24) bilobed, very heavily chitinised and with two lateral lobes pointing backwards. Penial complex (fig. 25): parameres free apically and with a median chitinised plate.

Length of body, 2·9-3·1 mm.
Length of forewing, 4·2-4·4 mm.
Length of antennae, 4·2 mm.

Habits. The specimens were found under the peeling bark of *Eucalyptus viminalis.* Generally the nymphs occurred in colonies under old loose bark on the bases of the trees, while the adults and also some nymphs were found in the upper branches under bark which had just begun to peel.

Locality. Scott's beach (near Ulverstone), N.W. Coast, January 22, 1949, 72 nymphs; February 13, 1949, 17 males, 6 females, 4 nymphs; Ulverstone, N.W. Coast, February 4, 1949, 40 nymphs.

This species has already been recorded from Tasmania by Tillyard (1923, p. 187).

Myopsocus griseipennis (MacLachlan, 1866)

Psocus griseipennis MacLachlan, 1866.

(Figs 26-32)

FEMALE

Colour. Epicranium pale yellow with dark brown lines and a wider pale brown line in the middle of each epicranial plate passing down to the ocellar tubercle; median epicranial suture brown; frons pale yellow with a median brown area; clypeus pale yellow with dark brown converging lines and with the front edge brownish-grey; anteclypeus brown; labrum pale brown except for the pale grey front edge; labium pale grey; jaws pale grey with two brown areas passing forwards from the bases of the eyes; ocellary tubercle grey; ocelli reddish-brown and ringed with black; eyes dark brown; first and third segments of maxillary palps pale brown, second segment grey, distal segment dark brown; first segment of antennae pale brown, second and third segments reddish-brown, distal segments dark brown.

Prothorax brown. Mesothorax: antedorsum dark brown with a median yellow T-shaped area, the column of the T ending anteriorly; lateral dorsa dark brown with the parts in contact with the T of the antedorsum and the posterior lateral edges yellow; scutellum grey. Metathorax: antedorsum grey; lateral dorsa pale brown; scutellum brown. First leg: coxa and trochanter grey; femur grey with pale brown markings in the median and distal regions; tibia pale brown with the distal extremity dark brown; proximal half of first tarsal segment pale brown, the remainder and the claws dark brown. Second and third legs similar except for the dark brown coxal segments.

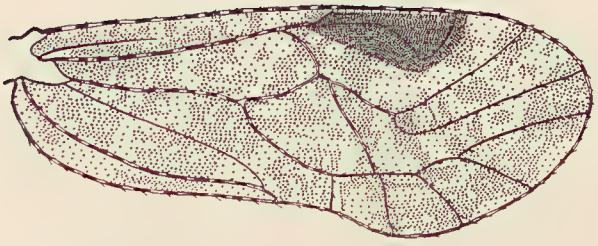
Forewing (fig. 26) brown with darker grey markings over the whole surface; pterostigma dark reddish-brown, the pigmented area extending slightly below the limits of *r1*; proximal veins, except for the pale grey vein *an*, with alternating brown and pale yellow regions; distal veins brown; margin with alternating brown and yellow regions; membrane with gold to green iridescence. Hindwing (fig. 26) pale brown, darker at the distal end of the wing and in cells Cu and Ax; veins and margin brown except for the yellow vein *r1* and the apical margin, which has alternate pale brown and pale yellow regions; membrane with red to gold iridescence.

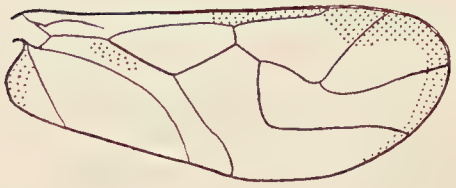
Abdomen grey with a reddish-brown band on each segment; apex of abdomen, except for the dark brown genitalia, pale brown.

Morphology. Head subtriangular in front view, semicircular in side view; median epicranial suture distinct; clypeus large and overhanging; ocelli three, close together; eyes prominent and of moderate size, interspace three times apparent eye diameter; lacinia (fig. 27) with two teeth, the larger with two rows of smaller teeth; mandibles normal; maxillary palps hairy with the end segment slightly dilated; antennae short with thick, short hairs; head with short hairs.

Prothorax small, almost hidden and hairless; mesothorax with short hairs on the anterior half, the remainder and the metathorax hairless.

Legs hairy; tibia with two apical spurs; claws (fig. 31) with a preapical tooth, a well developed pulvillus and a stiff basal bristle; ratio of tarsal segments of the third leg 7 : 1 : 1; first tarsal segment of the third leg with 21 hairs having pectinate bases, the second segment with one and the third without these hairs.





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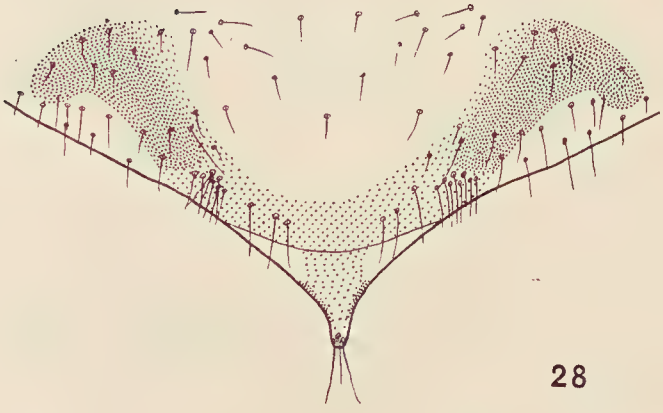

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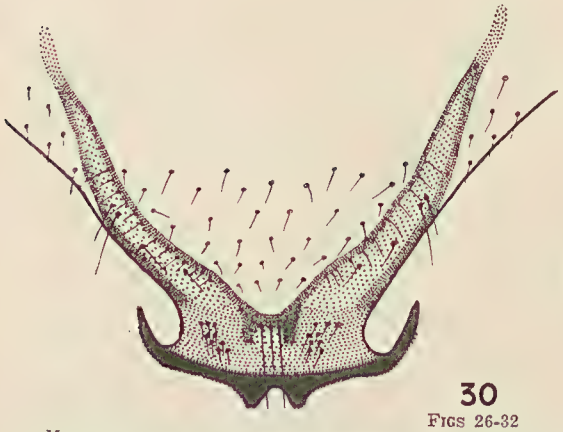

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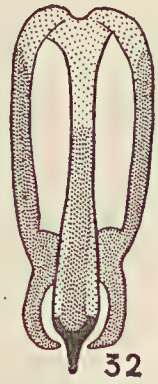

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FIGS 26-32

Myopsocus griseipennis (MacLachlan). Fig. 26: wings (female). Fig. 27: lacinia (female). Fig. 28: subgenital plate (female). Fig. 29: gonapophyses (female). Fig. 30: hypandrium (male). Fig. 31: claw (female). Fig. 32: penial complex (male).

Wings (fig. 26) minutely punctate. Forewing with short hairs on the margin and all the veins except *an*; greatest width one-third length. Greatest width of hindwing two-fifths length.

Abdomen large and oval; epiproct rounded, paraprocts pointed; subgenital plate (fig. 28) with a single median lobe carrying three hairs. Gonapophyses (fig. 29): ventral valves small and reduced; dorsal valves large, strongly chitinised and ending in a sharp point; external valves rounded.

Length of body, 3·6-3·8 mm.
Length of forewing, 3·4-3·6 mm.
Length of antennae, 2·8 mm.

MALE

Colour. Slightly darker than the female especially in the antennae, legs and wings; ventral surface of abdomen white; subgenital plate dark brown.

Morphology. Smaller in size and much more fragile than the female. Eyes larger, interspace twice apparent eye diameter; ocellary tubercle prominent.

Epiproct similar to but smaller than that of *M. australis* (fig. 21); semicircular with two prominent anterior lobes ending in sharp points. Paraprocts long and slender with the distal end curved upwards. Hypandrium (fig. 30), similar to that of *M. australis*, heavily chitinised and possessing two small median lobes and two large lateral lobes directed backwards. Penial complex (fig. 32): parameres free apically and with a median chitinised plate.

Length of body, 2·0-2·1 mm.
Length of forewing, 3·0-3·2 mm.
Length of antennae, 3·0 mm.

Habits. Specimens were found in large numbers under stones in dry localities; the insects are colonial. The eggs are laid in masses.

Locality. Domain, Hobart, February 28, 1949, 7 males, 22 females, 46 nymphs.

This species has been previously found in Tasmania and recorded as *M. australis* (Brauer) by Hickman (1934, p. 85).

Genus **Pentacladus** Enderlein, 1906

Forewing with numerous brown confluent areas; veins and wing margins with short hairs; media three- to five-branched; *r* and *m* fused for a short distance. Hindwing with *r* and *m* fused for a moderate distance; a few hairs present on the anterior margin. Claws with a preapical tooth, a well developed pulvillus and a stiff basal bristle. Hypandrium of male bilobed; parameres closed, but with two apical lobes and a median lamina. Subgenital plate of female ending in a blunt point and bearing hairs; gonapophyses with long and sharp ventral valves, small and thin dorsal valves and triangular external valves.

Pentacladus eucalypti Enderlein, 1906

(Figs 33-51)

FEMALE

Colour. Epicranium dark brown, each segment with a dark red streak passing from the top of the head down between the eyes, alongside the lateral ocelli and through the frons to the upper border of the clypeus; frons dark brown with a pale brown area around the base of the antennae; clypeus brown, lateral edges

becoming paler; anteclypeus white; labrum brown with pale brown lateral borders; proximal portion of labium white, distal portion deep purple; jaws dark brown; ocelli pale pink; eyes brick red; first two segments of maxillary palps pale brown, distal segments nearly black; first two segments of antennae white, third segment testaceous, distal segments brown.

Prothorax pale brown. Mesothorax: posterior border of the antedorsum red; a red area present on each lateral dorsum on the outer and posterior border; posterior borders of the lateral dorsa dark brown; scutellum dark brown; remainder of mesothorax brown. Metathorax dark brown. First leg: coxa white with a pale red area on the outer posterior border; trochanter white; femur white becoming brown distally; tibia testaceous; first tarsal segment brown, other segments and claws dark brown. Second and third legs similar to the first except for the dark brown coxae.

Forewing hyaline; shaded areas brown except as follows:—anterior two-thirds of areola postica yellowish-red; a reddish-brown spot posterior to the joining of *r* and *m*; posterior half of pterostigma yellow, the colouring continuing down to *rr*; posterior border of pterostigma red; anterior halves of cells M1, M2, M3 and M4 pale yellowish-brown. Veins: proximal portion of $m + cu$ red, middle portion yellow, distal end red; proximal halves of *r*, *an* and *ax* yellow, distal halves of *r* and *ax* brown, that of *an* red; *m* and *cu* red, other distal veins and borders of the wing brown except for the small distal yellow portions of $r + m$, *m* and *rr*; membrane hyaline with deep blue to violet iridescence. Hindwing (fig. 33): basal half of wing pale brown with darker brown patches in cells Cu and An; apex of the wing pale brown; all veins brown except the reddish-brown veins *an* and *ax*; membrane hyaline with red to gold iridescence.

Abdomen: dorsal surface brown with red bands in the middle of each segment; ventral surface white marked with brown; upper surface of epiproct red, lower surface white; paraprocts white on the inside, reddish-brown on the external surfaces, the sensory plates being dark brown. Valves of gonapophyses dark brown proximally becoming paler distally.

Two specimens collected were of a much paler colour than that given in the above description; both the red and the brown areas were paler in each case.

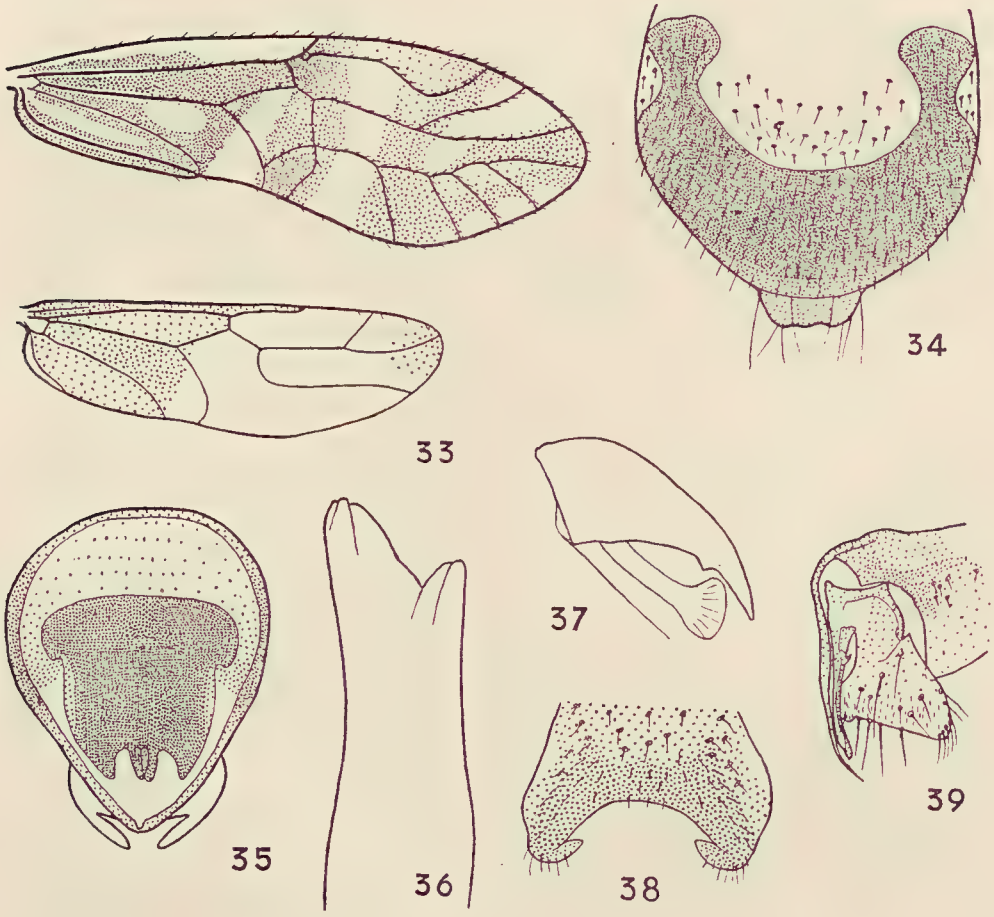
Morphology. Head sub-rectangular in front view, oblong in side view; median epicranial suture fine; clypeus slightly protruding; ocelli three, close together; eyes of moderate size, interspace two-and-a-half times apparent eye diameter; lacinia (fig. 36) with two teeth; mandibles normal; maxillary palps hairy with the distal segment slightly oval; antennae long with thick, short hairs and a few long hairs on each segment; head with long hairs on the epicranium, otherwise covered with short hairs.

Prothorax small, hairless and almost hidden; meso- and meta-thorax hairy. Legs hairy; tibia with three apical spurs; claws (fig. 37) with a small rather flat preapical tooth, a large pulvillus and a basal hair; ratio of the tarsal segments of the third leg 6 : 1 : 1½; first tarsal segment of the third leg with 21 hairs possessing pectinate bases, second and third segments without pectinate hairs.

Wings (fig. 33) just reaching beyond the end of the abdomen; greatest width one-third length. Forewing with the margin and all the veins except *ax* possessing short hairs; pterostigma with two or three short hairs. Veins of hindwing hairless; margin near $r2 + 3$ with three or four short hairs.

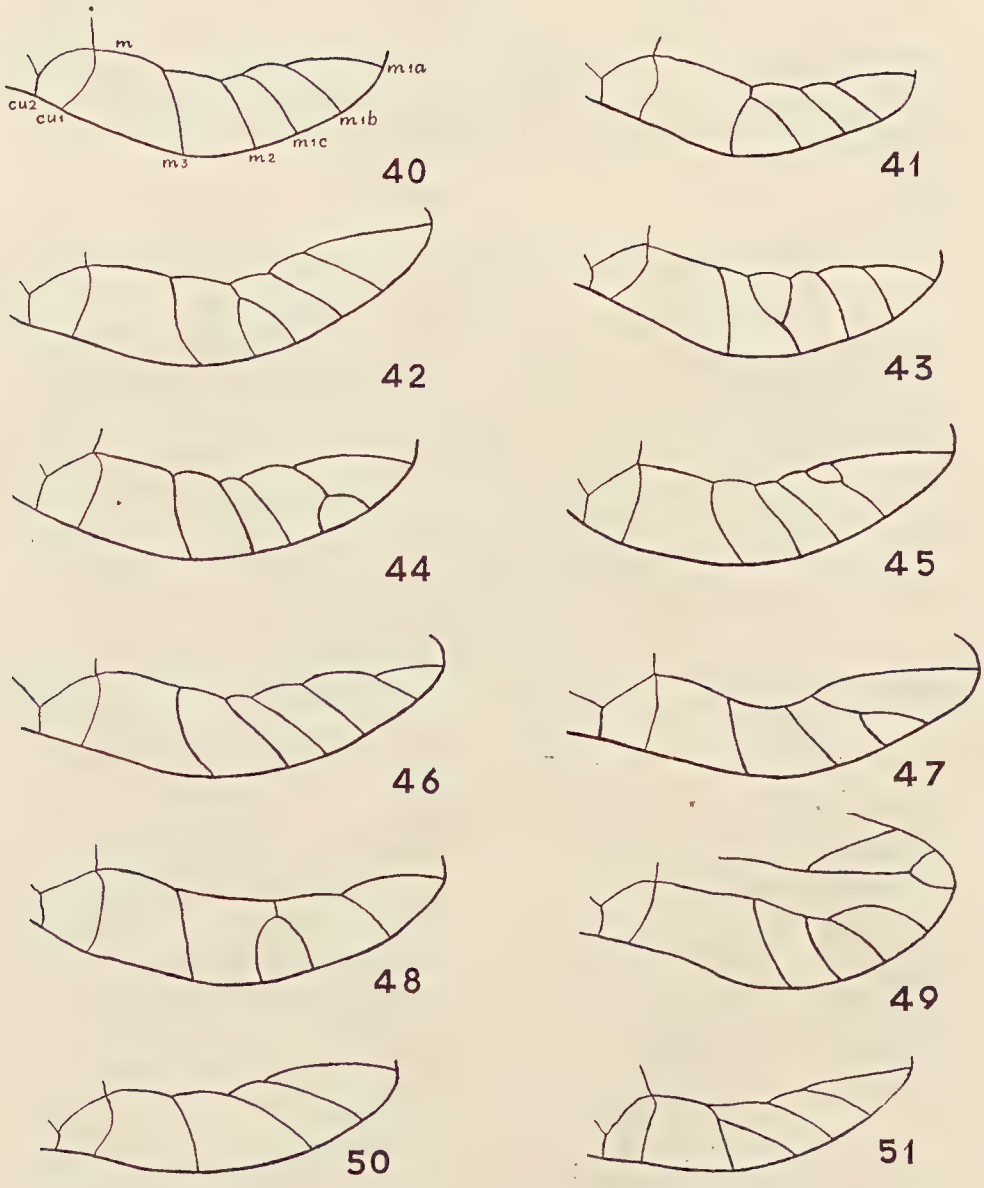
Abdomen large and oval, covered with short hairs; paraprocts large and rectangular; epiprocts wing-like; subgenital plate (fig. 34) bilobed. Gonapophyses (fig. 39): dorsal valves slender and short; external valves large, triangular and bearing long hairs; ventral valves long and slender.

Length of body, 3·5 mm.
Length of forewing, 3·3 mm.
Length of antennae, 3·8 mm.



FIGS 33-39

Pentacladus eucalypti Enderlein. Fig. 33: wings (female). Fig. 34: subgenital plate (female). Fig. 35: penial complex (male). Fig. 36: lacinia (female). Fig. 37: claw (female). Fig. 38: hypandrium (male). Fig. 39: gonapophyses (female).



FIGS 40-51

Pentacladus eucalypti Enderlein. Fig. 40: naming of the branches of the media. Figs 41-51: variations in the branching of the media.

MALE

Colour. Very similar to that of the female; hypandrium (fig. 38) nearly black.

Morphology. Eyes larger and more prominent than in the female, interspace twice apparent eye diameter. Wings and antennae of greater length than those of the female. Body small, the abdomen oval and curved upwards posteriorly.

Hypandrium (fig. 38) bilobed, the lobes curving inwards at their extremities. Penial complex (fig. 35): parameres joining apically and with two free apical lobes.

Length of body, 2·6 mm.
Length of forewing, 3·5 mm.
Length of antennae, 4·2 mm.

Variations in the Branching of the Media in Both Sexes

In 91 (54 males, 37 females) of the 174 adult specimens examined, the branching of the media was found to be different from the normal type (fig. 40). This indicates that the wing venation of this species is not constant and that the generic character based on the five branches of the media as stated by Enderlein (1906) does not hold in all cases.

The different variations found are as follows:—

m3 branched posteriorly, 10 males, 2 females (fig. 41).
m2 branched posteriorly, 11 males, 5 females (fig. 42).
m2 branched anteriorly, — males, 1 female (fig. 43).
m1b branched posteriorly, 6 males, 1 female (fig. 44).
m1b branched anteriorly, 3 males, 1 female (fig. 45).
m1a branched posteriorly, 2 males, 8 females (fig. 46).
Media 4 branched, *m1b* branched posteriorly, 8 males, 3 females (fig. 47).
Media 4 branched, *m2* branched posteriorly, 2 males, 2 females (fig. 48).
Media 4 branched, *m3* + *4* branched posteriorly, 3 males, 2 females (fig. 51).
Media 4 branched, *r4* + *5* branched distally, 8 males, 10 females (fig. 49).
Media 4 branched, — males, 1 female (fig. 50).
Media 3 branched, 1 male, 1 female.

Habits. The insects were found on thick, dead *Eucalyptus* leaves. They occur singly.

Locality. Rheban, E. Coast, May 25, 1949, 3 males, 3 females; May 27, 1949, 4 males, 5 females; Rifle Range, Hobart, May 1, 1949, 1 female; June 5, 1949, 5 males, 3 females; June 6, 1949, 10 males, 6 females; August 2, 1949, 4 males, 3 females; August 31, 1949, 9 males, 14 females, 2 nymphs; September 4, 1949, 22 males, 17 females; September 13, 1949, 25 males, 11 females; September 28, 1949, 24 males, 5 females.

Genus **Tricladellus** Enderlein, 1906

Forewing with numerous brown confluent areas; veins and wing margin with short hairs; venation similar to that of the genus *Psocus* with the areola postica joined to the media at a point or by a short transverse vein. *r* and *m* meeting at a point in the forewing, fused for a moderate distance in the hindwing. Claws with a small flat preapical tooth, a thin pulvillus and a basal hair. Hypandrium of the male lobed; parameres free apically and with a median chitinised plate. Subgenital plate of female bilobed, the lobes with long hairs; dorsal and ventral valves long and slender; external valves large and rectangular.

Brachypterism common.

Tricladellus froggatti Enderlein, 1906

(Figs 52, 54-59)

Female

Colour. Head dark brown, shining; front edge of labrum pale brown; anterior edge of labium reddish-brown, proximal portion white; region of ocellary tubercle darker than the surrounding surface; ocelli pale pink; eyes dark reddish-brown; proximal segments of maxillary palps dark brown, distal end of fourth segment black; first segment of antennae pale brown, second segment brown, third segment testaceous, the remaining segments dark brown.

Prothorax brown; mesothorax black and shining; metathorax similar to the mesothorax except for the brown antedorsum. First leg: coxa white, trochanter pale brown; tibia testaceous; first tarsal segment brown, other segments dark brown; claws black. Second and third legs similar to the first except for the dark brown coxae.

Wings (fig. 52) hyaline. Forewing: basal third deep brown except for the colourless anterior part of the costal cell and colourless areas in the middle of cells Cu and An; a narrow oblique greyish-brown band stretches from the proximal end of the pterostigma to the areola postica; a small greyish-brown area is situated near the most posterior part of the pterostigma, stretching to vein *m* and enclosing within it a large yellow spot just anterior to the branching of *rr*; another band of similar colour stretches from the anterior end of *r4 + 5* to a position slightly proximal to the end of *m3*, passing through the distal part of R5, through cells M1 and M2 and leaving hyaline mid-distal areas in the latter two cells; pterostigma with proximal and distal dark brown markings; basal halves of veins *r*, *m + cu*, *an* and *ax* together with *cu2* pale yellow; distal half of *an* reddish-brown; all other veins and parts of veins dark brown; membrane with green to violet iridescence. Hindwing hyaline; costal cell brown; cell An with a median grey-brown area; veins pale brown except for the reddish-brown veins *an* and *ax*; margin of wing pale brown; membrane with red to gold iridescence.

Abdomen white with a brownish-red band around each segment becoming fainter on the ventral side; terga of the eighth and ninth segments dark brown; subgenital plate dark brown; external surfaces of epiproct and paraprocts pale brown, internal surfaces pale yellow; sensory plates of paraprocts ringed with dark brown. Gonapophyses pale brown on the outside, white on the inside surfaces.

Morphology. Head sub-rectangular in front view, semicircular in side view; median epicranial suture distinct; clypeus rounded, protruding; ocelli three, close together; eyes of moderate size, interspace two-and-a-half times apparent eye diameter; lacinia (fig. 54) with two teeth; mandibles normal; maxillary palps long and hairy, distal segment slightly oval; antennae long with thick, short hairs and a few long hairs on each segment. Head, except for the jaws, covered with long hairs.

Mesothorax with a few long hairs, pro- and meta-thorax hairless. Legs hairy; tibia with three apical spurs; claws (fig. 56) long and slender, with a very small flat preapical tooth, a well developed pulvillus and a basal hair; ratio of the tarsal segments of the third leg 4 : 1 : 1½; first tarsal segment of the third leg with 17 hairs with pectinate bases, the second and third segments without these hairs.

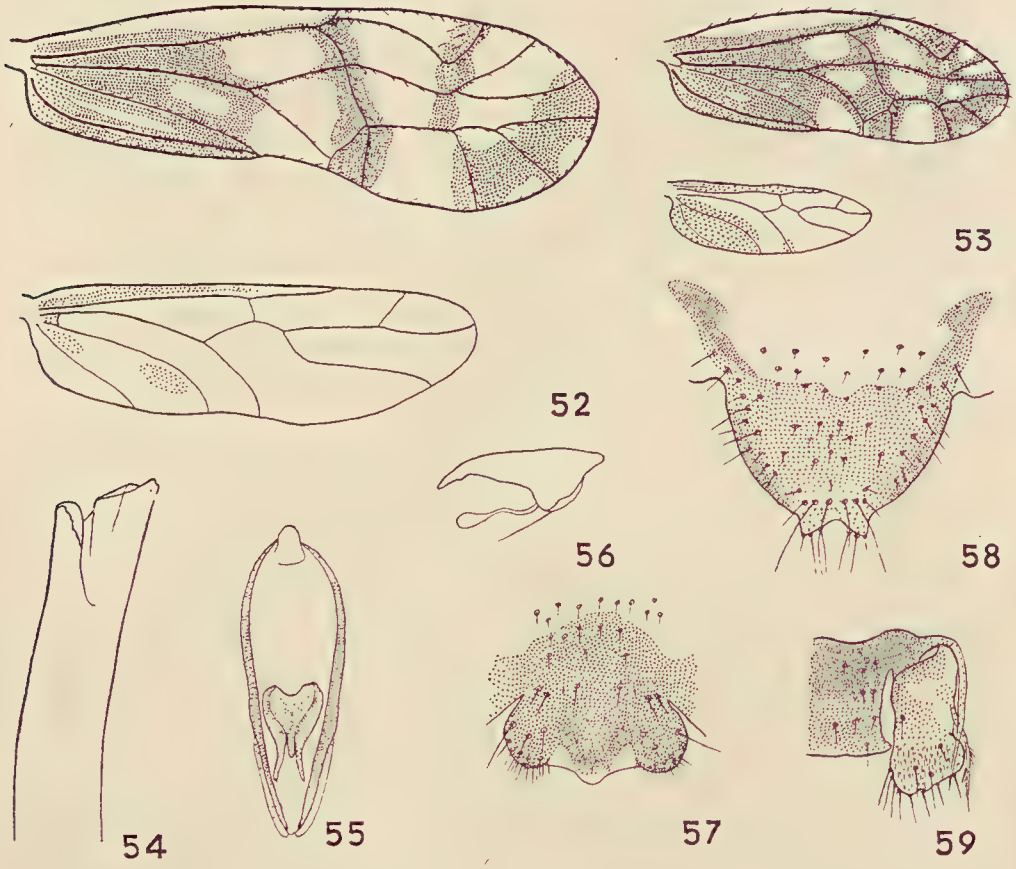
Forewing (fig. 52) with a few very short hairs on the margin and all the veins except *an*; pterostigma with a few short hairs; greatest width two-fifths length. Hindwing (fig. 52) hairless; greatest width one-third length.

Abdomen large and oval; epiproct rounded; subgenital plate (fig. 58) with two short lobes carrying long hairs. Gonapophyses (fig. 59): ventral and dorsal valves long and slender with acute apices; external valves large and rectangular.

Length of body, 2·9 mm.
Length of forewing, 2·8-3·0 mm.
Length of antennae, 3·05 mm.

MALE

Colour. Maxillary palps black, antennae dark brown; hypandrium dark brown; colour of remainder similar to the female.



FIGS 52-59

Tricladellus froggatti Enderlein. Fig. 52: wings (female). Fig. 53: brachypterous wings (female). Fig. 54: lacinia (female). Fig. 55: penial complex (male). Fig. 56: claw (female). Fig. 57: hypandrium (male). Fig. 58: subgenital plate (female). Fig. 59: gonapophyses (female).

Morphology. Body small; abdomen short and slender and curved upwards posteriorly; hypandrium (fig. 57) trilobed. Penial complex (fig. 55): parameres free apically and with a median chitinised plate.

Length of body, 2·0 mm.
Length of forewing, 2·5-2·7 mm.
Length of antennae, 3·05 mm.

Habits. The insects have been found singly on the leaves of dead *Eucalyptus* trees.

Locality. Rheban, E. Coast, May 25, 1949, 6 males, 5 females, 15 nymphs; Rifle Range, Hobart, June 6, 1949, 4 males, 2 females.

Tricladellus froggatti var. brachypterus n. var.

(Fig. 53)

In most specimens this variety does not differ from the macropterous form except in the development and pigmentation of the wings. Nine specimens (4 males, 5 females) were paler in colour than the normal forms.

FEMALE

Colour of Wings. Forewing (fig. 53) with markings similar to those of the macropterous form but larger in area and darker in colour; veins surrounded by dark brown. Hindwing (fig. 53) with costal cell, cells An and Ax and the posterior portion of cell Cu marked with brown; a small brown area present at the extremity of vein *cu*; all veins dark brown.

Morphology of Wings. Forewing: veins, margin and the distal part of the pterostigma with a few short hairs; greatest width two-fifths length. Hindwing hairless; greatest width one-third length.
Length of forewing, 1·8-1·9 mm.

MALE

Wings very similar to those of the female except in size.
Length of forewing, 1·6-1·7 mm.

Habits. The specimens were found in association with the macropterous form on the dry leaves of dead *Eucalyptus* trees.

Locality. Rheban, E. Coast, May 25, 1949, 25 males, 28 females; Rifle Range, Hobart, June 6, 1949, 2 males, 2 females.

Tricladellus nitens (Hickman, 1934)

(Figs 60-65, 67)

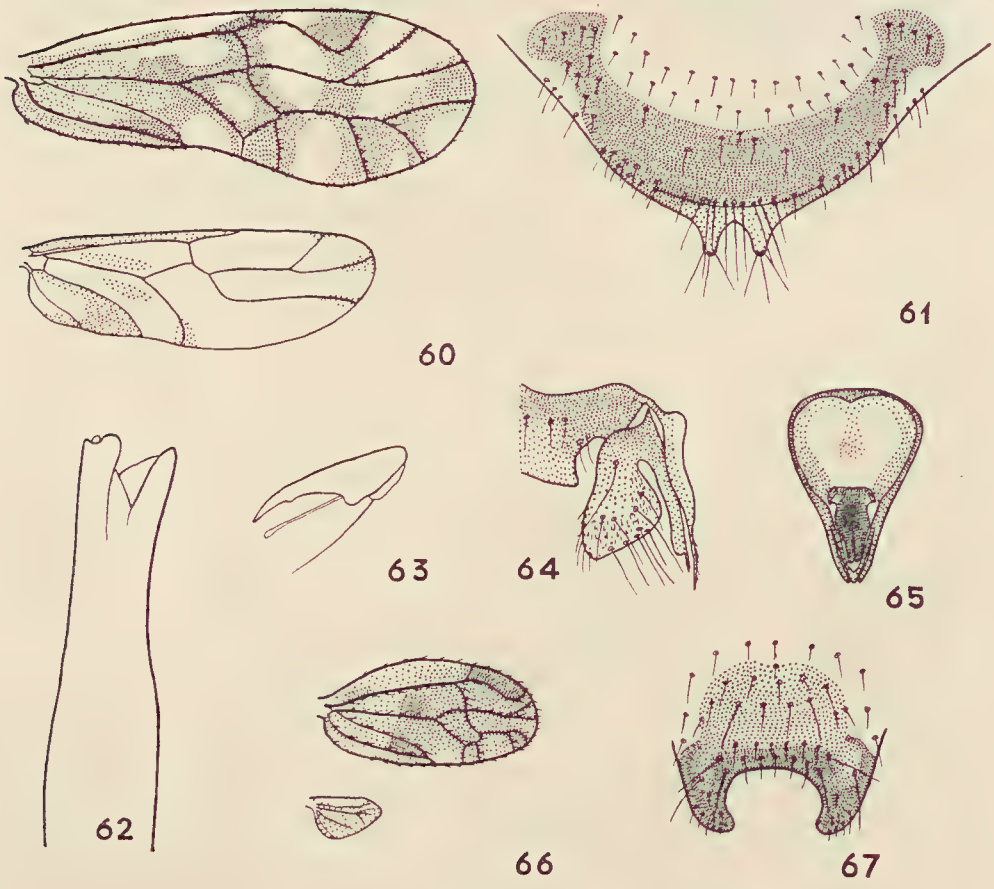
Myopsocus nitens Hickman (1934, p. 85).

FEMALE

Colour. Head dark brown and shining with a lighter brown area immediately above the eyes; median epicranial suture black; anteclypeus white; labrum brown with the anterior edge pale reddish-brown; proximal portion of labium pale brown, distal portion pale reddish-brown; ocelli pale red; eyes dark reddish-brown; first three segments of maxillary palps dark brown, distal segment nearly black; first segment and the basal halves of the second and third segments of the antennae pale brown, distal halves of the second and third segments and all the remaining segments dark brown.

Prothorax pale brown; meso- and meta-thorax dark brown and shining. Segments of first leg brown except for the dark brown tarsal segments and the black claws. Coxae of the second and third legs dark brown, other segments similar to those of the first leg.

Wings (fig. 60) hyaline. Forewing: basal third brown with colourless areas in cells Cu and An; a brown band extends from the proximal end of the pterostigma to the areola postica, joining up with proximal markings around veins *m* and *cu* and with distal markings around vein *m*; another brown band extends from the most posterior portion of the pterostigma down to the forking of *m3*, along *m* to the forking of *m2* and continuing to finish just anterior to the end of vein *r2 + 3*; proximal end and the distal third of the pterostigma dark brown; basal halves of *r*, *m + cu*, *an* and *ax* and the fork of *rr* pale yellow; distal half of *an* and *r1* and *cu2* reddish-brown; other veins dark brown; membrane with green to violet iridescence. Hindwing: anterior cell pale brown; pale brown areas at the extremities of the veins and in cells Cu and An; proximal veins pale brown, distal veins dark brown; membrane with red to gold iridescence.



FIGS 60-67

Tricladellus nitens (Hickman). Fig. 60: wings (female). Fig. 61: subgenital plate (female). Fig. 62: lacinia (female). Fig. 63: claw (female). Fig. 64: gonapophyses (female). Fig. 65: penial complex (male). Fig. 66: brachypterous wings (female). Fig. 67: hypandrium (male).

Abdomen pale brown dorsally with dark brown lateral and ventral surfaces; a white area present anterior to the subgenital plate; subgenital plate dark brown; apex of the abdomen pale brown except for the dark brown outer surfaces of the epiproct and paraprocts.

Morphology. Head triangular in front view, semicircular in side view; median epicranial suture distinct; clypeus large and bulging; ocelli three, close together; eyes small and protruding, interspace three times apparent eye diameter; lacinia (fig. 62) with two teeth; mandibles normal; maxillary palps hairy, the end segment slightly oval; antennae long, covered with short hairs and with several long hairs on each segment; hairs on the epicranium long, the remainder of the head with short hairs.

Prothorax small, hairless and nearly hidden; mesothorax hairy, metathorax hairless. Legs hairy; tibia with three apical spurs; claws (fig. 63) with a small preapical tooth, a well developed pulvillus and a basal hair; ratio of tarsal segments of the third leg 6 : 1 : 2; first tarsal segment of the third leg with 17 hairs having pectinate bases, other tarsal segments without pectinate hairs.

Wings (fig. 60) minutely punctate; greatest width one-third length. Forewing with very short hairs on the veins and wing margin. Hindwing hairless.

Abdomen oval and covered with short hairs; paraprocts large and rounded; subgenital plate (fig. 61) bilobed. Gonapophyses (fig. 64): ventral and dorsal valves long and slender with acute apices; external valves large and rectangular.

Length of body, 3·0 mm.
Length of forewing, 2·8 mm.
Length of antennae, 2·5 mm.

MALE

Colour. Differs from the female in having head and thorax slightly darker; abdomen brown dorsally, pale brown ventrally; hypandrium dark brown.

Morphology. Body short; antennae longer than in the female; abdomen short and oval, curved upwards posteriorly; hypandrium (fig. 67) bilobed, the lobes curving inwards distally. Penial complex (fig. 65): parameres free apically and with a median chitinised plate.

Length of body, 2·1 mm.
Length of forewing, 2·8 mm.
Length of antennae, 3·0 mm.

Habits. Specimens were found in large numbers in heaps of dry grass. The eggs are laid in groups on the larger grass stems and are covered by a dark grey encrustation.

Size of eggs, 0·49 x 0·26 mm.

Locality. Hobart, March 26, 1949, 3 males, 3 females, 8 nymphs; June 6, 1949, 3 males, 4 females; June 26, 1949, 8 males, 7 females, 6 nymphs.

Tricladellus nitens var. brachypterus n. var.

(Fig. 66)

Similar to the macropterous form in all characters except in the reduction and pigmentation of the wings.

FEMALE

Colour of Wings. Forewing (fig. 66) with the distal third pale brown and the proximal two-thirds dark brown except for an almost colourless area at the distal end of cell Cu; pterostigma very dark brown; basal halves of veins

r, *m* + *cu*, *an* and *ax* and the posterior border of cell Cu pale yellowish-brown; other veins and the remainder of the margin dark brown. Hindwing (fig. 66) a uniform pale brown colour with the veins slightly darker.

Morphology of Wings. Forewing: veins and wing margin with longer hairs than in the normal form; greatest width two-fifths length. Hindwing with veins greatly reduced and not reaching to the wing margin; veins and wing margin hairless; greatest width one-half length.

Length of forewing, 1·4 mm.

MALE

Wings very similar in colour and morphology to those of the female.
Length of forewing, 1·2 mm.

Habits. This variety was found, together with the macropterous form, in dry grass heaps. At the times collected, it occurred in larger numbers than the macropterous form.

Locality. Hobart, March 26, 1949, 12 males, 10 females; June 6, 1949, 15 males, 16 females; June 26, 1949, 23 males, 19 females.

Group HOMILOPSOCIDEA Pearman

Family *PHILOTARSIDAE* Pearman

Adults: tarsi with three segments; antennae with 13 segments; claws with a preapical tooth, a small thin pulvillus and a stiff basal bristle; margin and veins of wings hairy, the two rows of hairs on the posterior distal margins crossing over each other; pterostigma not joined to the radial fork; areola postica free.

Larvae possessing glandular hairs.

Genus **Philotarsus** Kolbe, 1880

Pterostigma convex posteriorly; *r* and *m* fused for a moderate distance in both wings; *rr* strongly arched in the forewing; *r* and *ax* with two rows of hairs; areola postica high. Subgenital plate of female with a tongue-like lobe; gonapophyses complete; dorsal valves in the form of conical lobes. Hypandrium of male with tubercles; parameres dilated; paraprocts with very long trichobothria.

Eggs ovoid, deposited singly and covered with a granular layer.

Philotarsus greyi n.sp.

(Figs 68-75)

FEMALE

Colour. Epicranial plates white with longitudinal black markings and a median brown area in each; frons white with brown markings; clypeus white with black nearly longitudinal lines; anteclypeus pale brown; labrum black with the anterior edge pale grey; proximal portion of labium pale grey, distal portion brown; lower half of jaws white, upper half brown; ocellary tubercle black; ocelli pale brown; upper half of eyes grey, lower half black; first three segments of maxillary palps white, distal segment black; proximal segments of antennae brown, distal segments dark brown.

Prothorax dark brown; mesothorax with the scutellum, the posterior edges of the lateral dorsa and the edges and dividing lines between the segments brown, the remaining areas black; metathorax with the scutellum and antedorsum brown,

the lateral dorsa black and the dividing lines between the segments brown. First leg: coxa white with a dark brown proximal edge; trochanter testaceous; femur testaceous with dark brown markings; tibia brown, tarsal segments and claws black. Second and third legs similar to the first leg except for the dark brown coxae.

Forewing (fig. 68) with greyish areas in every cell, the membrane otherwise being hyaline; pterostigma pale brown with darker areas around the hairs and with a band of pale orange around its posterior boundary; veins grey becoming darker distally; membrane with green to gold iridescence. Hindwing (fig. 68) hyaline except for the grey anterior cell and the grey distal portion of cell An; proximal veins brown, becoming black in the middle of the wing and grey distally; membrane with red to gold iridescence.

Dorsal surface of abdomen white with numerous large brown areas; ventral surface white with pale brown lines between the segments; subgenital plate dark brown with a very pale brown median lobe; paraprocts white with a black sensory field; epiproct white below, pale brown above; tergum of ninth segment dark brown. External valves white on the outside, dark brown on the inside surfaces; dorsal valves dark brown; ventral valves white.

Morphology. Head sub-rectangular in front view, semicircular in side view; median epicranial suture fine; clypeus slightly bulging; eyes rather small, interspace three times apparent eye diameter; ocelli three, close together; end segment of the hairy maxillary palps slightly oval; lacinia (fig. 73) with three main teeth; mandibles normal; antennae of moderate length, covered with short hairs and with a very long hair at the extremity of the distal segment. Head covered with short hairs, those on the epicranium being longer.

Prothorax small, hairless and nearly hidden; mesothorax with, metathorax without, hairs. Legs hairy; tibia with two apical spurs; claws (fig. 72) with a preapical tooth, a thin pulvillus and a basal hair; ratio of tarsal segments of the third leg 8 : 1 : 1¼; 21 hairs with pectinate bases on the first tarsal segment of the third leg, one on the second segment, the third segment without pectinate hairs.

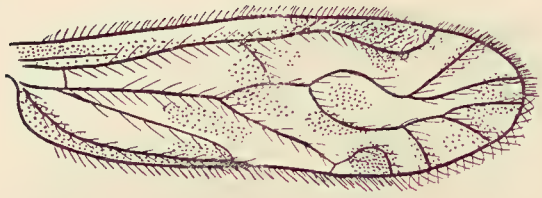
Wings hardly passing beyond the end of the abdomen; greatest width one-third length. Forewing (fig. 68): veins, margin and pterostigma hairy. Hindwing (fig. 68) with hairs on the distal portions of *r4 + 5* and *m* and along the margin from the end of *r1* around the apex of the wing to the proximal end.

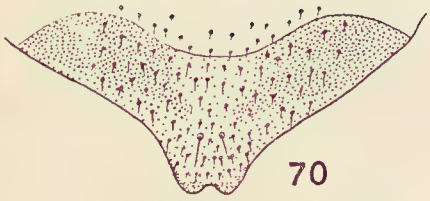
Abdomen large and oval with very short hairs on each segment; subgenital plate (fig. 75) with a median conical lobe which narrows at its posterior end. Gonapophyses (fig. 74): dorsal valves large and sub-rectangular; ventral valves long and slender with acute apices; external valves semi-circular.

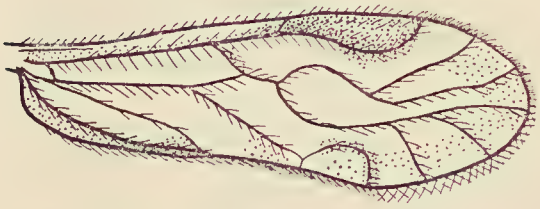
Length of body, 3·2 mm.
Length of forewing, 2·9 mm.
Length of antennae, 1·7 mm.

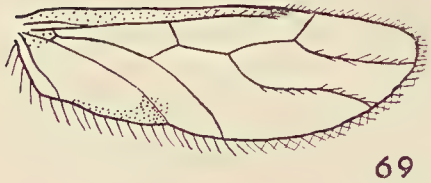
Male

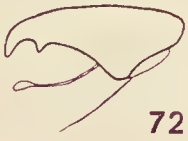
Colour. Differs from the female in the following: proximal segments of maxillary palps brown, end segment dark brown; tarsi brown; wings (fig. 69) much less darkly pigmented; pterostigma with orange and dark brown around its posterior boundary; hypandrium pale brown.

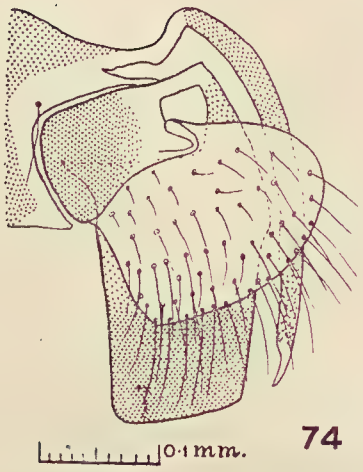


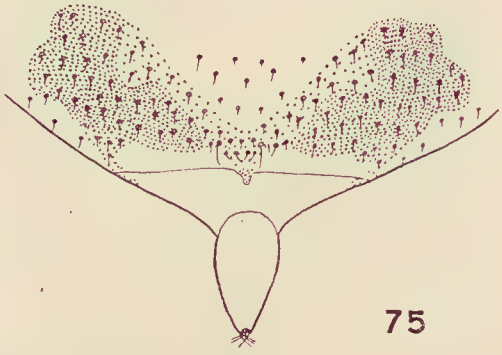












FIGS 68-75

Philotarsus greyi n.sp. Fig. 68: wings (female). Fig. 69: wings (male). Fig. 70: hypandrium (male). Fig. 71: penial complex (male). Fig. 72: claw (female) Fig. 73: lacinia (female). Fig. 74: gonapophyses (female). Fig. 75: subgenital plate (female).

Morphology. Head very much smaller than in the female; ocellary tubercle prominent; eyes large, interspace twice apparent eye diameter; antennae longer than in the female and covered with long dense hairs; wings longer than those of the female; hindwing with hairs on *r1* and hairs for a greater distance along *m1* and *r4 + 5* than in the female; body short with the abdomen curved upwards posteriorly; epiproct small; hypandrium (fig. 70) bilobed. Penial complex (fig. 71): parameres dilated.

Length of body, 2·4 mm.
Length of forewing, 3·1 mm.
Length of antennae, 2·1 mm.

Habits. Specimens were found on the underside of leaves of a large number of different trees. Three specimens were also obtained from under the loose bark of *Eucalyptus regnans*. The insects occur singly.

Locality. Type specimens collected New Town creek, March 11, 1949, 1 male, 1 female; Clayton creek, N.W. Coast, February 5, 1949, 1 male, 1 female, 1 nymph (Dr. Grey Edwards); Domain, Hobart, February 28, 1949, 1 female, 3 nymphs; April 7, 1949, 8 females, 12 nymphs; Bellerive beach, March 11, 1949, 17 males, 13 females, 54 nymphs; New Town creek, March 3, 1949, 2 males, 3 females, 22 nymphs; Rifle Range, Hobart, April 26, 1949, 4 males, 4 females, 1 nymph.

Type. Holotype (female) and allotype (male) in the Australian Museum, Sydney.

This species is named after the author's brother (Dr. Grey Edwards). The species differs from other Philotarsids in the pigmentation of the wings, the shape of the egg-guide and the sub-rectangular form of the dorsal valves.

Family *TRICHOPSOCIDAE* Pearman

Adults: tarsi with two segments; antennae with 13 segments; claws without teeth, with a dilated pulvillus and a basal hair; veins of forewings with long hairs; areola postica free; pterostigma not joined to the radial fork; *r* and *m* fused for a moderate distance in both wings. Hypandrium of the male simple; gonapophyses of the female with three pairs of well developed valves; subgenital plate simple.

Eggs covered by an encrustation and without a web.

Genus **Trichopsocus** Kolbe, 1882

Forewing: pterostigma sub-rectangular; areola postica flattened; *an* without hairs; *ax* with two rows of long hairs. Hindwing: one row of hairs on the margin from the end of *r1* to *r4 + 5*; posterior margin with alternate long and short hairs. Penial bulb of male with a variable chitinisation. Gonapophyses of female with conical dorsal valves ending in a sharp point; external valves nearly circular and with long hairs, the exterior hairs with recurved points; epiproct with two large hairs on each side of a short median hair and, situated below the latter on the posterior edge, two thick hairs; border of paraprocts with a large and a smaller hair, the two enclosing a small very fine hair.

Trichopsocus australis n.sp.

(Figs 76-82)

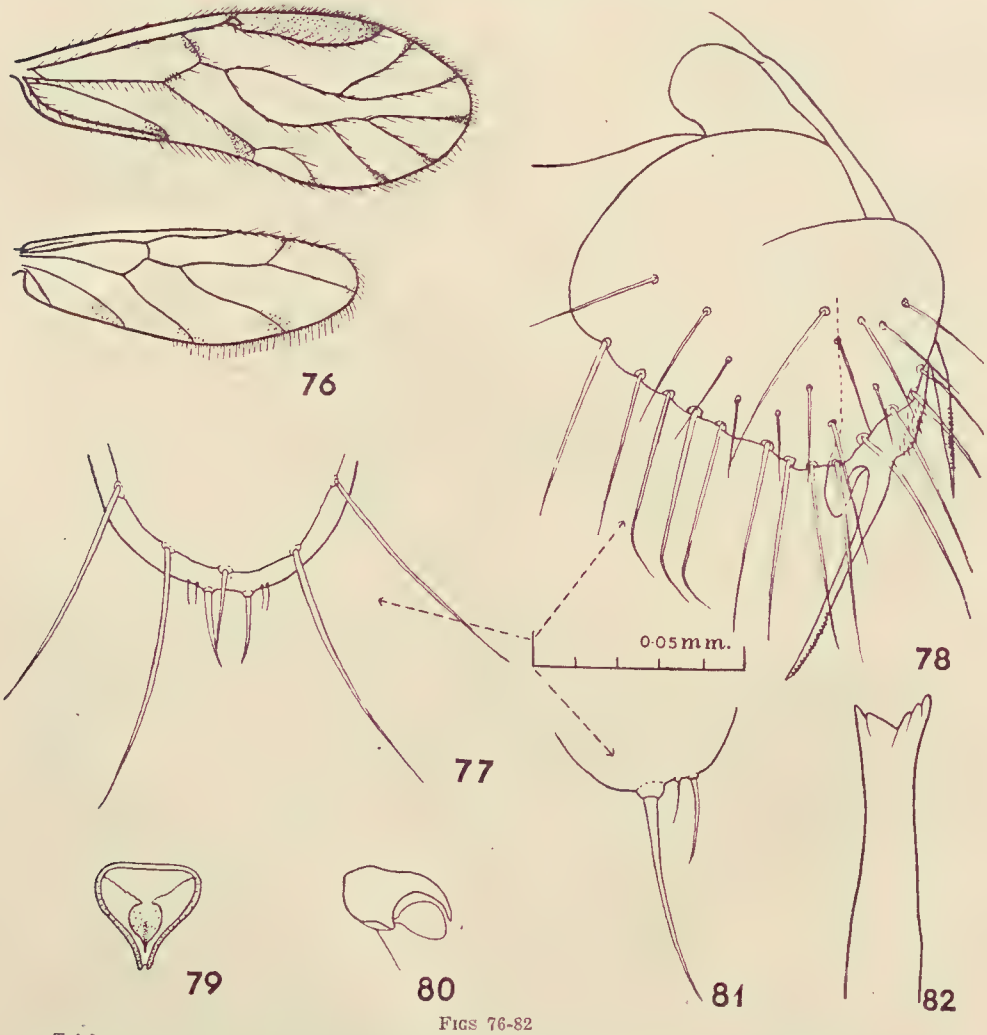
FEMALE

Colour. Head pale yellowish-white; a brown spot present between the eyes and the base of the antennae; front edges of labrum and labium pale brown; ocellary tubercle brown; ocelli pale brown; eyes greyish-green; basal segments of maxillary palps testaceous, distal segment pale brown; antennae testaceous becoming darker distally.

Prothorax pale yellow. Mesothorax pale yellow except for the pale brown lateral dorsa, which have brown posterior edges. Metathorax: antedorsum and anterior halves of the lateral dorsa pale yellow; posterior halves of lateral dorsa pale brown; scutellum brown. Legs testaceous with the distal tarsal segment and the claws dark brown.

Wings (fig. 76) hyaline. Forewing with brown areas at the ends of all the veins and in the distal portion of the pterostigma; *r* and *m* marked with brown proximal to their fusion; veins, except for the yellow vein *r1*, pale brown becoming darker towards the wing apex; pterostigma pale yellow with the distal portion brown; membrane with reddish-brown iridescence. Hindwing: brown areas present at the end of veins *an*, *m* and *r2* + *3*; pale brown at the end of *cu*; membrane with golden iridescence.

The abdomen, its apex and the gonapophyses pale yellow.



FIGS 76-82

Trichopsocus australis n.sp. Fig. 76: wings (female). Fig. 77: epiproct (female). Fig. 78: gonapophyses (female). Fig. 79: penial complex (male). Fig. 80: claw (female). Fig. 81: paraproct (female). Fig. 82: lacinia (female).

Morphology. Head triangular in front view, semicircular in side view; median epicranial suture very fine and indistinct; clypeus slightly bulging; ocelli three, close together; eyes of moderate size, protruding, interspace three-and-a-half times apparent eye diameter; lacinia (fig. 82) with two teeth; mandibles normal; maxillary palps hairy, end segment slightly oval; antennae of moderate length, covered with long hairs. Epicranium covered with long hairs, the rest of the head with short hairs.

Prothorax small, hairless and nearly hidden; mesothorax with a few long hairs, metathorax hairless. Legs hairy; tibia with two apical spurs; claws (fig. 80) without a preapical tooth, but with a dilated pulvillus and a basal hair; ratio of tarsal segments of the third leg 3 : 1; first tarsal segment of the third leg with 18 hairs having pectinate bases, second segment without pectinate hairs.

Forewing (fig. 76): veins, except *an*, and the margin hairy; *ax* with two rows of long hairs; pterostigma hairless; greatest width two-fifths length. Hindwing (fig. 76): veins hairless; margin hairy, the posterior apical portion with alternate long and short hairs; greatest width one-third length.

Abdomen oval and covered with short hairs; epiproct (fig. 77) and paraprocts (fig. 81) conforming to generic characters; subgenital plate simple. Gonapophyses (fig. 78): ventral valves long and slender and ending in a sharp point; dorsal and external valves normal.

Length of body, 1·55 mm.
Length of forewing, 2·0-2·6 mm.
Length of antennae, 1·6 mm.

MALE

Colour. Antennae much darker than in the female. Wings with brown areas paler and smaller in size than in the female.

Morphology. Antennae long with very long hairs; eyes larger than in the female, interspace three times apparent eye diameter; wings more constant in length than in the female.

Abdomen slender and curved upwards posteriorly; hypandrium simple. Penial complex (fig. 79): penial bulb weakly chitinised.

Length of body, 1·45 mm.
Length of forewing, 2·3-2·5 mm.
Length of antennae, 1·8 mm.

Habits. The insects were found singly on the underside of leaves of *Pittosporum* spp. and *Prunus* spp.

Locality. Type specimens collected Hobart, June 5, 1949, 1 male, 1 female; Hobart, May 30, 1949, 13 males, 5 females, 2 nymphs; June 5, 1949, 101 males, 66 females, 93 nymphs.

Type. Holotype (female) and allotype (male) in the Australian Museum, Sydney.

This species is very similar to *T. dalii* MacLachlan, 1867, but differs in the paler overall colour and in the markings of the forewing.

Family *PERIPSOCIDAE* Pearman, 1936

Adults: tarsi with two segments; antennae with 13 segments; forewing without areola postica.

Key to Genera

1. Forewing: *r* and *m* fused for a moderate distance; pterostigma rounded at the apex .... *Peripsocus* Hagen
   Forewing: *r* and *m* meeting at a point or fused for a short distance; pterostigma rectangular 2
2. Hindwing: *r* and *m* fused for a moderate distance .... *Interpsocus* n.gen.
   Hindwing: *r* and *m* joined by a transverse vein .... *Ectopsocus* MacLachlan

Genus **Peripsocus** Hagen, 1865

r and *m* fused for a moderate distance in both wings. Forewing; pterostigma tapering at the apex and with a pronounced rounded posterior angle. Claws with a preapical tooth, a filamentous pulvillus and a basal hair. Parameres of male joined anteriorly into a large thin plate and reunited apically at a point; penial bulb reinforced by thick chitin. Gonapophyses of female complete; ventral valves rather thick; dorsal valves short lobes with a dilated basal region and a tuft of large terminal hairs; external valves reduced.

Eggs deposited singly, engraved, with the apex slightly pointed; covered by a dark grey encrustation.

Peripsocus eucalypti n.sp.

(Figs 83-88)

Described as *Peripsocopsis milleri* Tillyard, 1923, by Hickman (1934, p. 87).

Female

Colour. Head pale brown except for white areas around the eyes, in the middle of each epicranial plate and on the jaws; median epicranial suture dark brown; anteclypeus white; labrum dark brown; front edge of labium brown; ocellary tubercle dark brown, ocelli pale pink; eyes black; first three segments of maxillary palps brown, distal segment dark brown; antennae pale brown becoming darker distally.

Prothorax pale brown, meso- and meta-thorax brown. Legs pale brown with the last tarsal segment and the claws brown.

Forewing (fig. 83): membrane semi-transparent; pale brown areas in the proximal halves of cells R1 and M; pale brown shading around some of the distal veins; veins pale brown becoming darker distally. Hindwing (fig. 83): cells pale brown; anterior cell slightly darker; veins pale brown except for the brown vein *cu*. Wing membranes with red iridescence.

Abdomen testaceous; a dark brown line along the mid-dorsal surface; segments ringed with dark brown. Gonapophyses brown except for the transparent ventral valves.

Specimens found in Southern Tasmania were slightly darker in colour than those from Northern Tasmania.

Morphology. Head sub-rectangular in both front and side views; median epicranial suture distinct; clypeus slightly protruding; ocelli three, close together; eyes small, interspace four times apparent eye diameter; lacinia (fig. 85) with two teeth; mandibles normal; maxillary palps hairy, distal segment long and slightly oval; antennae short with short hairs. Head with short hairs.

Prothorax small, hairless and nearly hidden; mesothorax with a few sparse, short hairs; metathorax hairless. Legs hairy, tibia with two apical spurs; claws (fig. 88) with a large preapical tooth, a thin pulvillus and a basal hair; first tarsal

segment of the third leg carrying 18 hairs with pectinate bases, second segment without pectinate hairs; ratio of tarsal segments of the third leg 2 : 1.

Wings with very short, sparse hairs; greatest width one-third length.

Abdomen large and oval, covered with short hairs; epiproct a large rectangular projection; subgenital plate (fig. 87) with a long median lobe slightly notched at its extremity. Gonapophyses (fig. 86) with external valves feebly developed, dorsal valves sub-rectangular and ventral valves pointed at the apex.

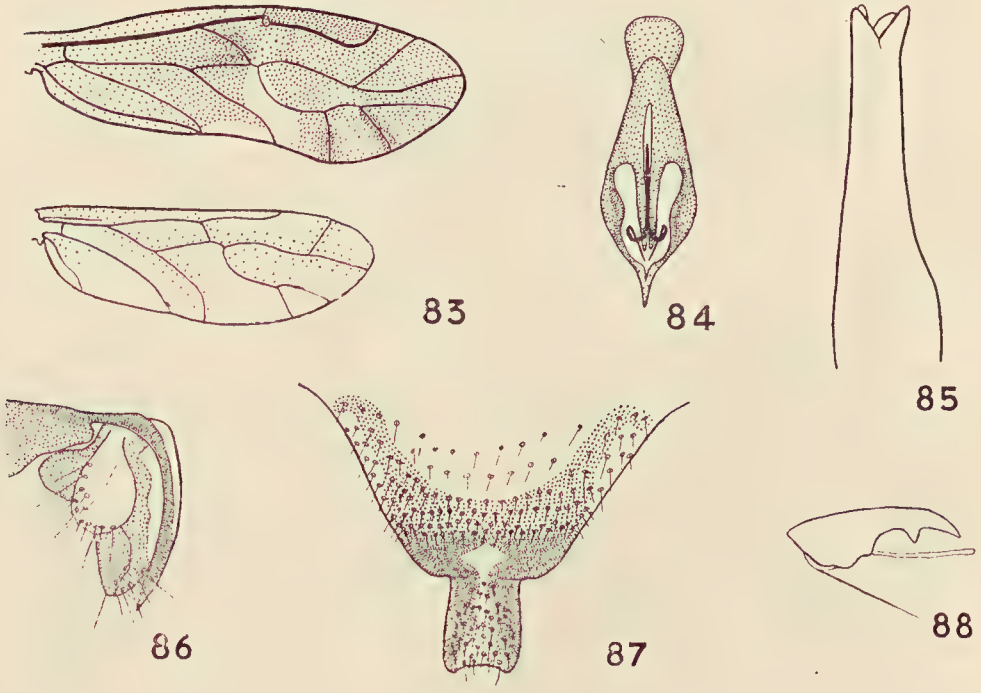
Length of body, 2·0 mm.
Length of forewing, 2·3 mm.
Length of antennae, 1·5 mm.

MALE

Colour. Slightly darker than the female in most areas.

Morphology. Eyes large, interspace three times apparent eye diameter; antennae longer than in the female. Thorax very thick dorso-ventrally. Abdomen curved upwards posteriorly; epiproct small and V-shaped; hypandrium simple and unlobed. Penial complex (fig. 84) normal for the genus.

Length of body, 1·5 mm.
Length of forewing, 2·3 mm.
Length of antennae, 1·7 mm.



FIGS 83-88

Peripsocus eucalypti n.sp. Fig. 83: wings (female). Fig. 84: penial complex (male). Fig. 85: lacinia (female). Fig. 86: gonapophyses (female). Fig. 87: subgenital plate (female). Fig. 88: claw (female).

Habits. Specimens have been found living under the loose bark of *Eucalyptus viminalis* and *Platanus orientalis.* The insects occur in colonies. The eggs are laid singly under loose bark on the trees and are covered by a dark grey encrustation.

Locality. Type specimens collected Ulverstone, N.W. Coast, January 24, 1949, 1 male, 1 female; Ulverstone, N.W. Coast, January 24, 1949; 6 males, 26 females, 54 nymphs; February 4, 1949, 5 females, 24 nymphs; Domain, Hobart, April 7, 1949, 8 males, 18 females, 14 nymphs.

Type. Holotype (female) and allotype (male) in the Australian Museum, Sydney.

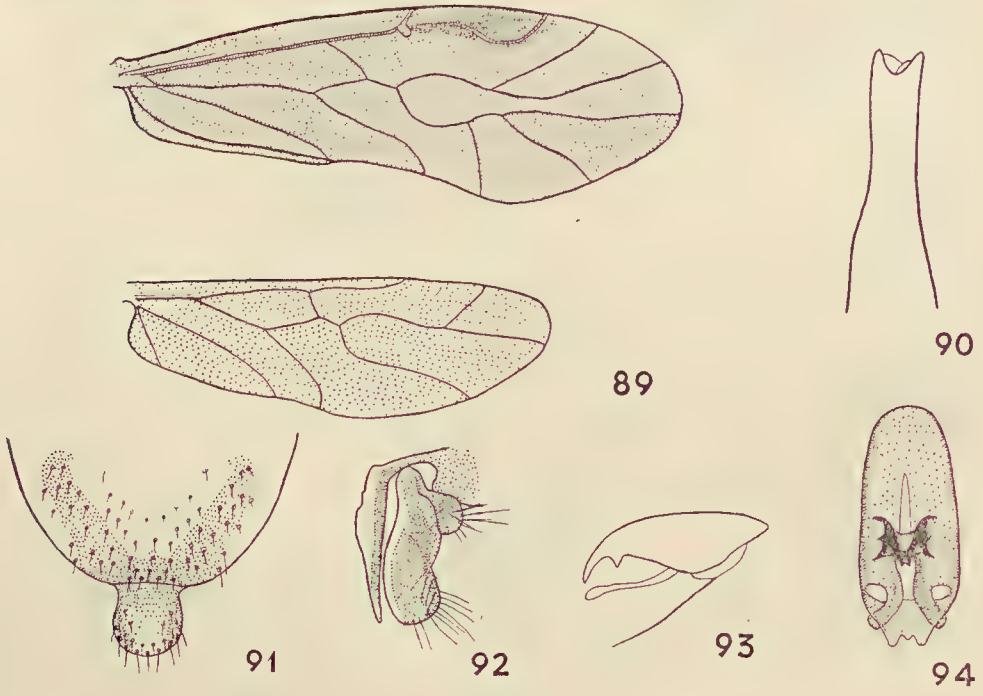
This species differs from other members of the genus in the colouring of the wings, the form of the penial complex and of the subgenital plate.

Peripsocus macropterus n.sp.

(Figs 89-94)

FEMALE

Colour. Epicranium white with pale brown around the edges of the epicranial plates; clypeus white, the posterior three-quarters marked with pale brown curved lines passing from front to rear; anteclypeus white; labrum dark brown; labium pale brown; ocellary tubercle dark brown; ocelli pale white; first segment of maxillary palps white, second and third segments pale brown, distal segment brown; antennae testaceous.



FIGS 89-94

Peripsocus macropterus n.sp. Fig. 89: wings (female). Fig. 90: lacinia (female). Fig. 91: subgenital plate (female). Fig. 92: gonapophyses (female). Fig. 93: claw (female). Fig. 94: penial complex (male).

Prothorax pale brown. Mesothorax: anterior half of antedorsum dark brown, posterior half pale brown; anterior two-thirds of lateral dorsa dark brown, remainder pale brown; scutellum pale brown. Metathorax: antedorsum white; lateral dorsa brown; scutellum very pale brown. Legs: coxa pale brown; trochanter and proximal half of femur white; distal half of femur, the tibia and the first tarsal segment pale brown; second tarsal segment and claws brown.

Wings (fig. 89) semi-transparent and pale brown; proximal veins testaceous, distal ones dark brown. Forewing: pterostigma and distal portion of anterior cell brown; membrane with red to gold iridescence. Hindwing: membrane with golden iridescence.

Abdomen brown with lemon-yellow to white areas on the anterior edges of the segments; dorsal surface with a median brown line along its length; subgenital plate and gonapophyses brown.

Morphology. Head sub-rectangular in front view; median epicranial suture distinct; clypeus slightly bulging; ocelli three, close together; eyes small, interspace three times apparent eye diameter; lacinia (fig. 90) with two teeth, the shaft enlarged distally; mandibles normal; maxillary palps long and hairy, end segment slightly oval; antennae short, covered with hairs. Head covered with short hairs.

Prothorax small, hairless and almost hidden. Mesothorax and metathorax hairless. Legs hairy, tibia with two apical spurs; claws (fig. 93) with a large preapical tooth, a thin pulvillus and a basal hair; ratio of tarsal segments of the third leg $2\frac{1}{2}$: 1; first tarsal segment of the third leg with 20 hairs with pectinate bases, other segment without these hairs.

Wings (fig. 89): veins and wing margin with short, sparse hairs; greatest width one-third length. Forewing with the posterior margin waved.

Abdomen large and oval with a few short hairs on each segment; subgenital plate (fig. 91) with a long median lobe; epiproct large and rectangular. Gonapophyses (fig. 92) rather small; external valves very feebly developed.

Length of body, 2·4 mm.
Length of forewing, 3·1-3·2 mm.
Length of antennae, 1·6 mm.

MALE

Colour. Generally much darker than the female, especially the head, thorax and legs.

Morphology. Eyes very large, interspace twice apparent eye diameter; ocellary tubercle prominent; antennae covered with long thick hairs; wings longer than in the female. Abdomen short, with short hairs and curved upwards posteriorly; epiproct rounded. Penial complex (fig. 94): parameres lobed at the apex, the lobes directed outwards and with a chitinised median plate.

Length of body, 2·1 mm.
Length of forewing, 3·5-3·6 mm.
Length of antennae, 2·4 mm.

Habits. The insects have been found singly on the leaves of a large number of trees.

Locality. Type specimens collected New Town creek, March 13, 1949, 1 male, 1 female; New Town creek, March 3, 1949, 2 males, 4 females; March 13, 1949, 5 males, 4 females, 19 nymphs; Waterworks Rd., Hobart, March 6, 1949, 5 males, 6 females, 12 nymphs; Hobart, May 30, 1949, 3 males, 2 females, 4 nymphs: June 5, 1949, 1 male, 1 female.

Type. Holotype (female) and allotype (male) in the Australian Museum, Sydney.

This species differs from other members of the genus in the large size of the wings, in the reduction of the external valves and in the distinctive form of the penial complex.

Genus **Interpsocus** n. gen.

Forewing: *r* and *m* meeting at a point; pterostigma rectangular; the three rami of the media close to each other; veins and margin hairy. Hindwing: *r* and *m* fused for a moderate distance; hairs on the distal anterior margin. Claws without a preapical tooth, with a dilated pulvillus and a basal hair. Parameres of male free apically and joined anteriorly into a large plate; penial bulb reinforced by thick, very dark chitin. Gonapophyses of female complete; ventral valves thick; dorsal valves dilated and without hairs; external valves dilated apically and with a tuft of large, terminal hairs.

The eggs are laid in groups and are covered by a dark encrustation. The web is formed of a few irregular strands which are overlaid with excrement.

The genus is separated from *Peripsocus* by the following: *r* and *m* meeting at a point in the forewing; pterostigma rectangular; form of claws and of subgenital plate of the female.

It differs from *Ectopsocus* in that *r* and *m* are fused in the hindwing and in the form of the male and female gonapophyses.

Genotype. Type species *Interpsocus brunneus* n.sp.

Interpsocus brunneus n.sp.

(Figs 95-102)

FEMALE

Colour. Epicranial plates dark brown; median epicranial suture black; frons and clypeus dark brown; anteclypeus white; labrum dark brown with a pale brown distal border; labium pale brown with a white anterior edge; ocellary tubercle black; ocelli dark reddish-brown; eyes nearly black; all segments of maxillary palps brown; first two segments of antennae dark brown, the remainder, except the two distal testaceous segments, brown.

Prothorax brown. Mesothorax dark brown with a reddish tinge on the anterior surface of the lateral dorsa. Antedorsum of metathorax brown, remainder dark brown. Legs: coxa brown; trochanter and femur testaceous; tibia pale brown with a distinct reddish tinge; tarsus and claws brown.

Wings (fig. 95): membranes with green to gold iridescence. Forewing: membrane pale brown with darker areas at the ends of all the veins and at both ends of the pterostigma; veins brown becoming darker distally. Hindwing: paler than the forewing except for the pale brown costal cell; veins dark brown proximally, becoming pale brown towards the wing apex.

Abdomen: dorsal surface pale brown with dark reddish-brown bands on each segment; ventral surface white; apex brown.

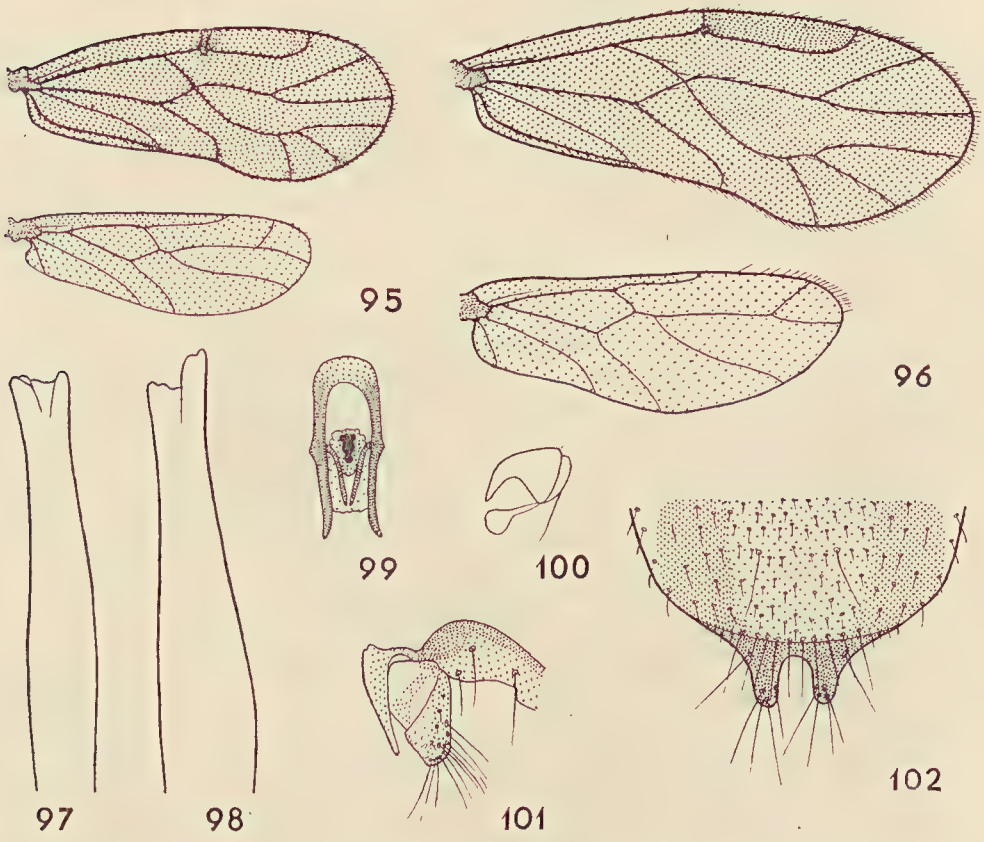
Morphology. Head sub-rectangular in front view, semi-circular in side view; clypeus of moderate size, slightly bulging; median epicranial suture distinct; ocelli three, close together; eyes small, interspace three times apparent eye diameter; lacinia (fig. 98) with two unequal teeth, the longer tooth of smaller width; mandibles normal; maxillary palps large and hairy with a slightly enlarged terminal segment; antennae short, covered with short hairs. Labrum and labium with short hairs, the rest of the head with long hairs.

Prothorax and metathorax hairless. Mesothorax covered with long hairs. Legs hairy; tibia with three apical spurs; claws (fig. 100) without a preapical tooth, but with a well developed pulvillus and a basal hair; ratio of tarsal segments of the third leg 2 : 1; first tarsal segment of the third leg with 16 hairs having pectinate bases, second segment without pectinate hairs.

Wings (fig. 95) with membranes minutely punctate. Forewing rounded at the apex and possessing short hairs on the margin and all the veins except *an*; greatest width two-fifths length. Hindwing with short hairs on the margin of cell R3; greatest width one-third length.

Abdomen large and oval; paraprocts rounded; epiproct triangular; subgenital plate (fig. 102) with two lobes each bearing four or five hairs. Gonapophyses (fig. 101) : ventral valves well developed; dorsal valves large and bearing apical spines; external valves lobe-like with long hairs.

Length of body, 2·4-2·6 mm.
Length of forewing, 2·3-2·4 mm.
Length of antennae, 1·6 mm.



FIGS 95-102

Interpsocus brunneus n.sp. Fig. 95: wings (female). Fig. 96: wings (male). Fig. 97: lacinia (male). Fig. 98: lacinia (female). Fig. 99: penial complex (male). Fig. 100: claw (female). Fig. 101: gonapophyses (female). Fig. 102: subgenital plate (female).

MALE

Colour. Head similar to that of the female except for the darker maxillary palps and antennae. Thorax, legs and abdomen lighter in colour than in the female. Genitalia dark brown.

Wings (fig. 96). Forewing pale brown; pterostigma slightly darker; veins dark brown proximally, becoming paler towards the wing apex. Hindwing very pale brown, the costal cell darker; veins paler than those of the forewing.

Morphology. Head small; lacinia (fig. 97) with teeth approximately equal in length; eyes large, interspace twice apparent eye diameter; antennae of moderate size and covered with long hairs; ocellary tubercle prominent.

Forewing (fig. 96) with the margin bulged posteriorly; hairs on the veins and margin longer than in the female; greatest width two-fifths length. Hindwing (fig. 96) with hairs on the anterior distal margin; greatest width one-third length.

Abdomen short, slender and curved upwards posteriorly. Penial complex (fig. 99): parameres free apically and joined anteriorly into a large thin plate; penial bulb reinforced by thick, very dark chitin.

Length of body, 1·7-1·9 mm.

Length of forewing, 2·3-3·0 mm.

Length of antennae, 2·1 mm.

Habits. The insects were found in groups of from six to eight in rolled *Eucalyptus* spp. bark. Single specimens have been taken from dry *Eucalyptus* leaves.

Locality. Type specimens collected Hobart, September 29, 1949, 1 male, 1 female; Swansea, E. Coast, May 28, 1949, 3 males, 1 female, 6 nymphs; Rifle Range, Hobart, June 1, 1949, 2 males; August 15, 1949, 12 females; September 29, 1949, 5 males, 6 females, 3 nymphs.

Type. Holotype (female) and allotype (male) in the Australian Museum, Sydney.

Genus **Ectopsocus** MacLachlan, 1894

Forewing: rounded at the apex and without accentuated curving of its posterior border; pterostigma rectangular; *r* and *m* often meeting at a point or fused for a short distance; veins generally straight, the three rami of the media close to one another. Hindwing with *r* and *m* joined by a transverse vein. Claws without preapical teeth, with a well developed pulvillus as an enlarged distal lamina and with a basal hair. Border of epiproct of male with a row of very serrated chitinous spurs; paraprocts chitinised apically. Gonapophyses of female variable, often with some valves reduced or absent.

Eggs deposited in groups, without an encrustation but covered by a web.

Ectopsocus froggatti Enderlein, 1906

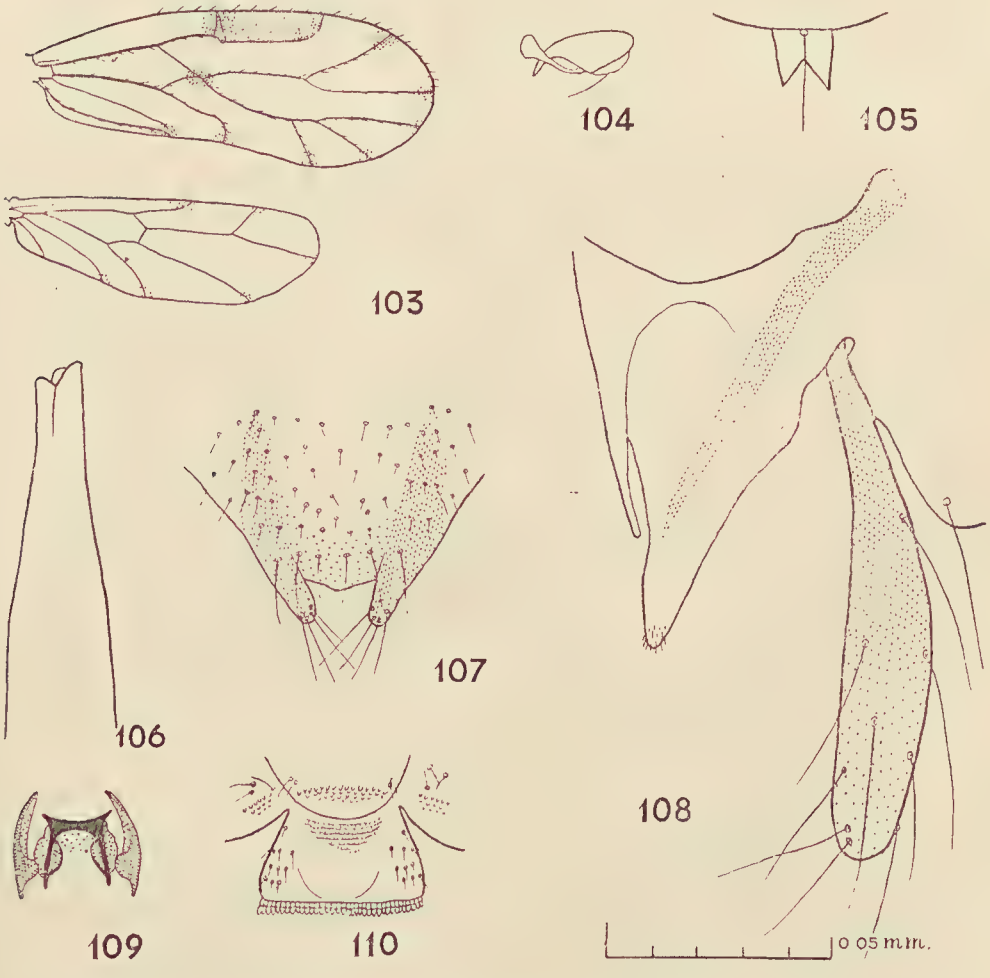
(Figs 103-110)

FEMALE

Colour. Epicranial plates pale brown with brown posterior edges and brown spots near the median epicranial suture and around the eyes; frons pale brown with brown anterior areas; clypeus brown with paler spots near the posterior boundary and with a pale brown anterior edge; anteclypeus pale grey; labrum brown with the anterior edge pale brown; labium pale grey with the distal edge brown; upper third of jaws brown, remainder white; ocellary tubercle pale brown; ocelli pale reddish-brown, inner boundaries dark reddish-brown; lower half of

eyes brown, upper half grey; first three segments of maxillary palps white, distal segment grey, darker towards the apex; antennae with first and the proximal half of the second segment dark brown, distal half of the second segment and the third segment grey, the remaining segments very dark brown.

Prothorax pale brown. Mesothorax: antedorsum dark brown with paler posterior edges; lateral dorsa brown with dark brown median areas; anterior half of scutellum dark brown, posterior half pale brown. Metathorax dark brown with the dividing lines between the segments pale brown. First leg: coxa, trochanter and femur white; tibia pale grey; tarsus grey; claws black. Second and third legs similar except for the greyish-brown proximal half of the coxae.



FIGS 103-110

Ectopsocus froggatti Enderlein. Fig. 103: wings (female). Fig. 104: claw (female). Fig. 105: border of paraproct (female). Fig. 106: lacinia (female). Fig. 107: subgenital plate (female). Fig. 108: gonapophyses (female). Fig. 109: apex of penial complex (male). Fig. 110: apex of ninth tergite and epiproct (male).

Wings (fig. 103): membranes with green to gold iridescence. Forewing very pale brown with darker areas at the ends of all the veins and at the junction of *r* and *m*; pterostigma white with dark brown proximal and distal ends; anterior proximal veins pale brown, posterior distal veins dark brown except for the reddish-brown vein *r1*. Hindwing paler than the forewing; vein endings with slightly darker areas; veins brown.

Abdomen: dorsal surface white with a dark brown band on each segment; ventral surface white; apex pale brown to white.

The colour of this species varies to a great degree; the most common pigmentation has been found to be the one described above, but some specimens have been found with a much paler overall colour and a few without brown spots on the wings and of a very pale body colour. The latter were found to be more common on leaves while the darker specimens were more common in less exposed situations such as under loose bark.

Morphology. Head triangular in front view, oblong in side view; median epicranial suture fine; clypeus prominent, bulging; ocelli three, close together; eyes small and prominent, interspace four times apparent eye diameter; lacinia (fig. 106) with two teeth; mandibles normal; maxillary palps hairy and with the end segment slightly oval; antennae of moderate length, covered with short hairs. Epicranium, frons and clypeus with long hairs, rest of the head with short hairs.

Prothorax small, hairless and nearly hidden. Anterior half of mesothorax with hairs, the rest hairless. Metathorax hairless. Legs hairy; tibia with two apical spurs; claws (fig. 104) without a preapical tooth, with a dilated pulvillus and a basal hair; ratio of tarsal segments of the third leg $2\frac{1}{2}$: 1; first tarsal segment of the third leg having 17 hairs with pectinate bases, second segment without such hairs.

Wings (fig. 103) minutely punctate. Forewing with short hairs on all the veins except *an*, *m* and *r*; anterior apical portion of the margin with short hairs; greatest width one-third length. Hindwing: veins hairless; a few short hairs present on the apex of the wing margin; greatest width one-third length.

Abdomen large and oval; apical border of paraproct (fig. 105) with a pair of sharp tubercles enclosing a hair; subgenital plate (fig. 107) bilobed, each lobe with three or four hairs of length 50-55 μ. Gonapophyses (fig. 108) reduced; ventral valves small and joined to the eighth sternite; dorsal valves in the form of small membranous lobes with toothed apices; external valves as long lobes with long hairs.

Length of body, 2·0 mm.
Length of forewing, 2·2-2·4 mm.
Length of antennae, 2·2 mm.

MALE

Colour. Slightly darker than the female. Darker areas on the wings larger. Gonapophyses (fig. 109) brown.

Morphology. Head much smaller than in the female; eyes large, interspace two-and-a-half times apparent eye diameter; ocellary tubercle prominent; wings longer than in the female, antennae shorter.

Abdomen short, slender and curved upwards posteriorly; epiproct and the end of the ninth tergite (fig. 110) with spines on their posterior edges. Penial complex (fig. 109): parameres forming a double arc.

Length of body, 1·5 mm.

Length of forewing, 2·6-2·9 mm.

Length of antennae, 2·1 mm.

Habits. This species is one of the most common in Tasmania. It occurs all the year round in many situations, e.g., under loose bark, on leaves of a large number of trees and on dry debris. The insects occur singly or occasionally, under loose bark, in groups of from two to four.

Locality. N.W. Coast, January-February, 1949, 7 males, 21 females, 37 nymphs; E. Coast, May, 1949, 14 males, 25 females, 33 nymphs; Hobart, March-April-May, 1949, 12 males, 55 females, 21 nymphs; September-October, 1949, 10 males, 28 females, 30 nymphs.

Group CAECILIETAE

Family *CAECILIIDAE*

Adults: tarsi with two segments; antennae with 13 segments; claws without a preapical tooth, with a pulvillus which is well developed as a thin lamina and with a basal hair. Veins of the wings with hairs in one or two rows; hairs on the margins always in several rows; areola postica always free; pterostigma not joined to the radial fork and without a transverse vein at its posterior angle. Gonapophyses of female reduced; hypandrium of male simple, parameres enclosed.

Eggs deposited in groups, without an encrustation but covered by a web.

Genus **Caecilius** Curtis, 1837

Wings rounded at the apex; margin of the forewing with very long, thick hairs; veins with a single row of hairs; pterostigma with a large posterior angle and often strongly bulged posteriorly; peduncle of the radial fork curved. Claws with large and dilated pulvilli. Gonapophyses of the female very constant; dorsal valves as long, regularly acute lobes, which are often chitinised on the outer surface; external valves reduced to feeble chitinous plates, situated at the base of the dorsal valves and carrying a hair (rarely two or three, the extra ones being shorter). Epiproct and paraprocts of the male ornamented externally; papillae chitinous, those on the epiproct carried on a swelling; chitinous tubercles of the paraprocts often variable.

Caecilius quercus n.sp.

(Figs 111-117)

FEMALE

Colour. Head testaceous with a faint yellowish tinge except for the following: epicranium and frons pale yellowish-brown; a brown area present around the posterior edge of the base of the antennae; anterior edges of labrum and labium pale brown; ocellary tubercle brown; ocelli pale brown; eyes brown; maxillary palps with the three proximal segments pale yellow, distal segment brown; first two segments of antennae pale brown, third and fourth testaceous, distal segments brown.

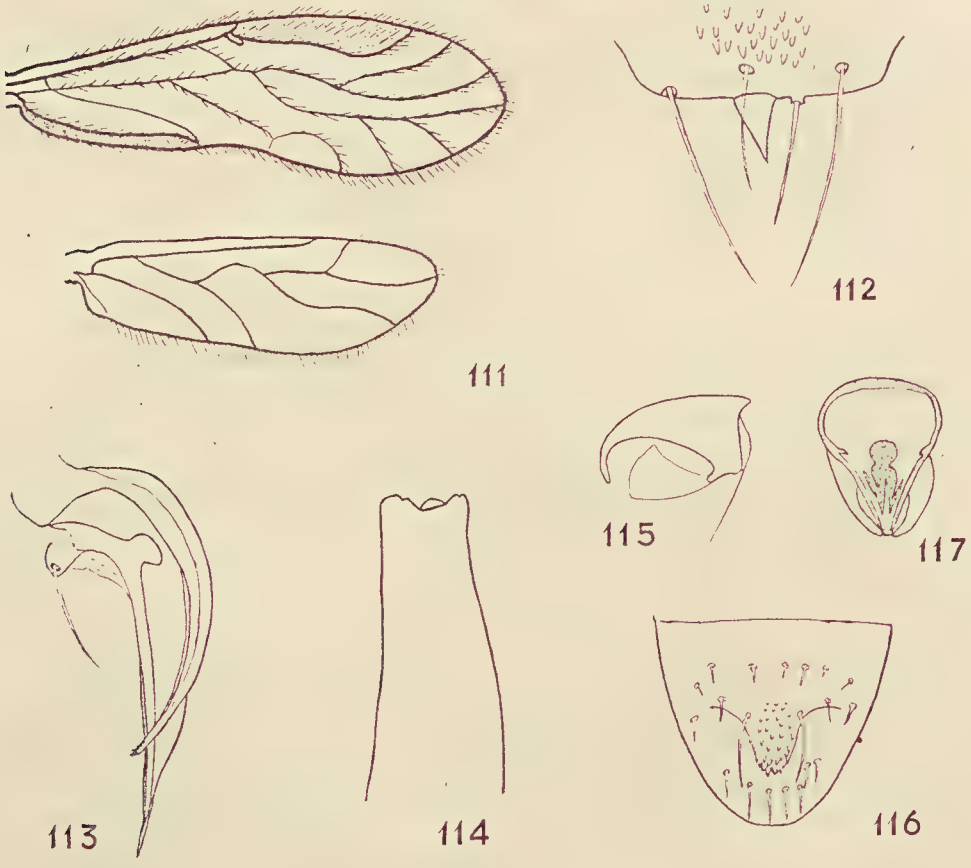
Prothorax pale brown; meso- and meta-thorax yellow with the anterior edge of the antedorsum and the boundaries between the antedorsum and the lateral dorsa brown in both cases. Legs testaceous with the distal extremity of the tibia, the second tarsal segment and the claws dark brown.

Forewing (fig. 111): pterostigma yellowish-brown; membrane pale yellowish-brown; cell Ax brown; veins pale yellow proximally, brown distally; membrane with green to gold iridescence. Hindwing (fig. 111) pale brown; veins pale yellow proximally, pale brown distally; membrane with a golden iridescence.

Abdomen and gonapophyses pale lemon-yellow.

Morphology. Head sub-rectangular in front view, semicircular in side view; median epicranial suture very fine; clypeus large and bulging; ocelli three, close together; eyes protruding, interspace two-and-a-half times apparent eye diameter; lacinia (fig. 114) with a blunt head, the teeth not clearly defined; mandibles normal; maxillary palps hairy, the distal segment slightly oval; antennae with thick, short hairs. Head covered with very short hairs.

Prothorax small, hairless and almost hidden; mesothorax well developed, covered with short hairs; metathorax with a few short hairs on the scutellum, otherwise hairless. Legs hairy; tibia with two apical spurs; claws (fig. 115) without a preapical tooth, with a dilated pulvillus and a basal hair; ratio of tarsal segments of the third leg $2\frac{1}{2}$: 1; first tarsal segment of the third leg with 21 hairs having pectinate bases, second segment without these hairs.



FIGS 111-117

Caecilius quercus n.sp. Fig. 111: wings (female). Fig. 112: border of paraproct (male). Fig. 113: gonapophyses (female). Fig. 114. lacinia (female). Fig. 115: claw (female). Fig. 116: epiproct (male). Fig. 117: penial complex (male).

Forewing (fig. 111) with all the veins except *an* hairy; pterostigma with small hairs on the anterior half and equal to one-third the length of the wing. Hindwing (fig. 111) without hairs on the veins; hairs on the margin from *r1* around the apex of the wing and along the posterior margin. Membranes of both wings minutely punctate; greatest width one-third length.

Abdomen large and oval with short hairs on each segment. Gonapophyses (fig. 113): dorsal valves long and slender; external valves with one basal hair.

Length of body, 2·9 mm.
Length of forewing, 3·1 mm.
Length of antennae, 3·1 mm.

MALE

Colour. Slightly darker than the female; eyes dark brown; segments of the antennae dark brown; edges of thorax dark brown enclosing a yellow, median, oblong area.

Morphology. Antennae and wings longer than in the female, the body much shorter and smaller; eyes large and prominent, interspace equal to the apparent eye diameter.

Abdomen slender, curved upwards posteriorly; epiproct (fig. 116) with tubercles carried on a swelling; border of paraprocts (fig. 112) with a triangular tubercle; hypandrium simple. Penial complex (fig. 117) normal.

Length of body, 2·1 mm.
Length of forewing, 3·3 mm.
Length of antennae, 3·2 mm.

Habits. Specimens have been found singly on the underside of leaves of a large number of trees.

The eggs are laid in groups of from six to twelve along the veins of the leaves, only one group being found on each leaf in the majority of cases. The eggs are covered by a circular web when laid on the outside veins and by a semicircular web when laid on the midrib. The eggs are oval in shape, white when first laid, later becoming dark brown on the exposed surface.

Size of eggs, 0·47 x 0·23 mm.

Locality. Type specimens collected Hobart, March 1, 1949, 1 male, 1 female; Hobart, March 1, 1949, 7 males, 13 females; March 30, 1949, 7 males, 1 female, 7 nymphs; May 30, 1949, 8 males, 1 female; June 5, 1949, 5 males, 10 females; Bicheno, E. Coast, May 25, 1949, 1 male, 2 nymphs; Swansea, E. Coast, May 26, 1949, 1 female, 4 nymphs; Ulverstone, N.W. Coast, June 18, 1949, 2 males, 1 female.

Type. Holotype (female) and allotype (male) in the Australian Museum, Sydney.

This species closely resembles *C. flavistigma* Tillyard, 1923, but differs in the colouring of the eyes, ocellar tubercle and antennae and in that *cu2* is without hairs in the forewing.

I wish especially to thank Professor V. V. Hickman for the help and interest he has shown while this work was being carried out.

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Pap. & Proc. Roy. Soc. Tasmania, 1949 (15th September, 1950)

The Intertidal Ecology of Tasmania

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With 2 Plates and 32 Text Figures

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It is proposed to study the detailed and general ecology of the intertidal region in Tasmania. It is hoped to obtain the general picture through the detailed study of several localities and by a study of the physical environment when such data are available for the locality under examination.

This paper is the first of a series on the intertidal ecology of the South of Tasmania. It is intended to extend the work to the North and other coasts at a later date.

Part I.—Introduction

(a) Short History of Littoral Ecology in Australia

Scientists have been attracted to the littoral region in Australia by the diversity and, in places, the extreme richness of the fauna. Hedley (1915) refers to this aspect of littoral conditions saying 'in species and individuals the local fauna is extremely rich, probably more so than in any marine area in the temperate zone of the Northern Hemisphere'. Whitelegge as early as 1889 listed 2136 species of the marine invertebrate fauna of Port Jackson (Whitelegge, 1889). Since then many species have been added to this list. This total compares very favourably with the Plymouth area, where over 2500 species, exclusive of parasites, were recorded (Marine Biological Association, 1931). This latter area has been more intensively studied than the Port Jackson area, especially as regards the smaller animals, and when knowledge of the Port Jackson area has reached a similar stage there will almost certainly be many more species than the Plymouth total.

In view of this very rich fauna a considerable amount of taxonomic study has been devoted to the littoral forms. A list of all the papers published on this topic would be irrelevant to this work, but some of the more important papers are given by Dakin, Bennett and Pope (1948). The littoral area around Sydney

has been particularly rigorously searched by taxonomists and it is little wonder that Dakin, Bennett and Pope *(loc. cit.)* expressed surprise at the fact that so little interest had been taken in the communities of the littoral region. Until recently only sporadic efforts to study these communities had been made.

In Australia, with the exception of the F.I.S. 'Endeavour' and Cronulla Station, there have never been permanent stations established with marine zoology as their sole occupation. Marine zoology has been a feature at Sydney University in recent years, but most of the marine research work has been carried out by individuals using University, Museum or private facilities. This situation must be compared with that in the North-East Pacific where there have been numerous stations operating over a considerable period of time. The Californian Academy of Sciences was established in 1853 but did not undertake marine work for some years. Stanford established the John Hopkins Marine Laboratory in 1891, the Universities of California and Washington opened marine laboratories in 1901 and 1909 respectively, while the University of British Columbia has been associated with the Pacific Biological Station for a number of years. These and other institutions have all been concerned with the various aspects of marine ecology, taxonomy and hydrology. Fraser (1942) gives a summary of the history of marine zoology on the Pacific coasts of Canada and America. In view of the uniqueness of the Australian marine fauna, its geographical extent and its richness, especially on the Barrier Reef and associated islands, it is to be deplored that no permanant marine stations have been set up in this country.

In Australia one of the first papers published as an ecological study was that of Tenison-Woods (1880). This paper was largely concerned with the Mollusca and discussed the range of various species. There was little of general ecological interest contained therein. Hedley (1915) described the ecology of the Sydney beaches. This was the first attempt to discuss the ecology of any one area. Of necessity, much detail was left out of this general account but it was a stimulating introduction. However, many years elapsed before other workers turned their attention to the area. Johnston about the same time was working on the ecology of Caloundra in Queensland and this region has been ignored since his paper was published (Johnston, 1917). The Great Barrier Reef Committee Reports contain little of direct ecological interest. Several publications of the Great Barrier Reef Expedition of the British Museum in 1929-30 are of ecological interest, notably those of Manton (1935), Stephenson and others (1931), Otter (1937), Yonge (1940), Marshall and Orr (1931) and Yonge and Nicholls (1931).

It was not until 1943 that the Sydney area again received attention when Pope (1943) instituted a survey of the animal communities of Long Beach. This time the interest in littoral ecology was much more sustained and Dakin, Bennett and Pope (1948) considered the salient ecological features of the coast of New South Wales.

The only other State where active ecological work has been proceeding is South Australia. Here the littoral algal communities of Kangaroo Island have been studied by Womersley (1946*a*, 1946*b*, 1947, 1948). Edmonds (1948) has described the distribution of animal species in the same locality.

(b) The Status of Marine Zoology in Tasmania

In the past marine zoology in Tasmania has suffered from neglect to a far greater degree than in other States. General zoology in Tasmania has also been generally neglected. A review of the contributions of the members of the Royal Society of Tasmania, has been published by Somerville (1943). The present status of general zoology has been described by Plomley (1949).

In Tasmania marine studies may be considered under two main heads (1) Taxonomic and (2) Ecological. The former of these may be further divided into the sub-littoral or dredged and the littoral studies.

The dredging has been conducted by both expeditions and individuals. The most important of these expeditions are the 'Challenger' (Bass Straits); 'Alert' (Bass Straits); Australian Antarctic Expedition, 1911-14 (off Maria Island); 'Endeavour' (in Bass Straits and off the East Coast). Individuals have conducted numerous dredging expeditions and the results of these trips are scattered in various journals. A great many of the earlier expeditions were not properly recorded and species described from these are simply mentioned as being found in Tasmania. The work of Haswell (1882) contains many Tasmanian references and the works of Dendy on sponges contain several Tasmanian records, as does that of Lendenfeld (1889). More recent additions to the marine fauna are to be found in Briggs (1914), Tweedie (1941), Flynn (1918), Shaw (1927), Clarke (1946), Guiler (1948), and others. The fishes are fully described in various works and are listed in Lord and Scott (1924).

Taxonomic work on the littoral fauna has been virtually neglected in Tasmania. Hickman (1948) describes the biology of littoral spiders, while May (1921, 1923) describes the Mollusca of Tasmania with scant notes as to habitat of each species. Very few other phyla have been mentioned and one is forced to attempt identification from literature referring to mainland forms or to describe the species before any work of ecological value can be undertaken. Apart from the two references mentioned in this context there has never been any attempt to systematically collect representatives of one phylum and to produce a detailed descriptive work on those species.

This lack of interest in the littoral fauna is probably due to the poverty of that fauna compared with the richness to be found at Sydney. The lower tidal zones of the shores are richer in forms that the upper zones, but there is difficulty in collecting in these zones due to the behaviour of the tides.

With such little attention having been paid to the littoral region in Tasmania it is therefore not surprising that no work has been attempted on the ecology of the intertidal region.

(c) Scope of the Present Work

The present work has been undertaken with a view to establishing some of the basic ecological features of the Tasmanian littoral region. In the initial stages it is intended to concentrate on the shores of the South of the island. The salient features of the other parts of the island will be examined for comparison with those noted in the South. It is to be observed that the South furnishes examples of exposed rocky coasts, various degrees of sheltered rocky coasts, sandy beach, mud, surf beaches, storm beaches and several lagoons. There are also two large rivers, the Derwent and the Huon, with numerous small streams. In the more detailed work it is intended to concentrate on the Derwent estuary, D'Entrecasteaux Channel and Frederick Henry Bay areas.

Part II.—Literature

In this review it is proposed to consider Australian works referring to marine ecology, and the relevant overseas literature on littoral ecology will be included in discussions of the various topics in this work.

The literature shows the evolution of littoral ecology in Australia. Ecological work has been of a very sporadic nature, but there is certain evidence that the present interest in this phase of marine biology will be maintained. The dates

of publication of the various papers on littoral ecology, 1880, 1915, 1917, 1931, 1943, 1946, 1947 and 1948, illustrate the fluctations of interest. The many Scientific Reports of the Great Barrier Reef Expedition contain much of ecological interest, those of Manton and Stephenson (1935) and Stephenson, Stephenson, Tandy and Spender (1931) being primarily concerned with ecology.

The first paper on littoral ecology in Australia by Tenison-Woods (1880) was of a very general nature and could have stimulated other workers to turn their attention to the study of the littoral region. The Mollusca dominated the paper and the author was concerned mainly with their distribution over a large area. The paper represents the tentative suggestions of a taxonomist, in this case a conchologist, who has become interested in the biotic relationships of the animals with which he has worked. Due to the then prevalent lack of knowledge of the physical environment, Tenison-Woods was only able to indicate the geographical range, habits and food of a number of species.

The study of littoral ecology was carried a stage further when Hedley (1915) applied the widening knowledge of the physical environment to the littoral area. The application was uncertain in nature and little consideration was given to the effect of the physical factors forming the environment. The bulk of the paper is devoted to the habitats and the habits of the forms found there.

Johnston (1917) described the habitats encountered at Caloundra and the forms inhabiting them, but gave no consideration to the physical environment.

In the studies of Pope (1943) the evolution of littoral ecology proceeded a step further in the form of a detailed study of the plant and animal communities of one limited area in the Sydney region. This paper represents the same stage, as do the Barrier Reef Expedition Reports mentioned above.

Dakin, Bennett and Pope (1948) extended this work to cover the features of a large area of coast and analysed the physical and biological features encountered. With a large team of workers this and the preceding stage can be carried out simultaneously.

Womersley (1946*a* and 1946*b*) considered the ecology of individual species of algae in a restricted area. His general accounts of the algal ecology of the area appeared in 1947 and 1948. Edmonds (1948) correlated the animals of the same area with the plant communities.

It must be stressed that, although one or more of these stages may be omitted, it is essential before attacking a specific problem to have a general knowledge of the major ecological features of the region in which the problem is being considered.

In the future, work of this nature lies in furthering our knowledge of general littoral conditions in Australia and in the study of the ecology of species and how they are built up into communities.

Detailed Review of the Literature

(a) On Some of the Littoral Marine Fauna of N.E. Australia

Tenison-Woods, J. E. Proc. Linn. Soc., N.S.W., Vol. 1, 1880, pp. 106-131

The author is primarily concerned with the mollusca and the survey covers the area between Trinity Bay and the Endeavour River. The author does not give any details of the physical environment. In this respect the paper may be severely criticised, but allowance must be made for the very undeveloped state of ecology at that time. Since the publication of this paper, Sumner and others (1914) have stated 'any investigation not based on a knowledge of physical data may be dismissed as futile'. The paper, however, contains a wealth of observations

on the habitats of various molluscan species and notes as to the geographic range of certain species. The author recognises three faunal types of coast, namely, coral reef, mangrove swamp and exposed rocky coast. His account contains little more than a list of the shells to be found on the coral reef areas while the mangrove swamps are also dealt with very briefly. The rocky coast has been studied more closely and the paper contains several references to the range and variations of some Tasmanian littoral species. In all three descriptions of faunal types of shore these are the notes of the keen observer on habits, food and enemies of various species.

(b) An Ecological Sketch of the Sydney Beaches

Hedley, C. Proc. Roy. Soc., N.S.W., 49, 1915, pp. 15-77

The author notes the physical environment as being composed of the following factors . . . nature of floor, temperature of air and sea, salinity and purity of the sea, tides and currents. The monthly averages of sea temperatures from 1881-90 are given. The author considered them too restricted to be of any great value. He further points out that, compared with overseas, the temperatures are fairly constant, varying from 75·5° F. on 15th and 20th January, 1887, to a minimum of 50·1° F. in July of the same year, a variation of 25·4° F. This comparison is difficult to substantiate, as the figures for Plymouth as quoted by Hedley only show a variation of 14·8° F. The temperatures for the English Channel are given by Lumby (1935), who analysed records extending over 25 years. The mean monthly temperature for March, 1908, is 9·18° C. and that for August is 15·75° C. These temperatures were taken in region 5. These figures, picked at random, show a much smaller range of variation than those given by Hedley. It is worth noting here that more valid figures for water temperatures are given by Dakin and Colefax (1940). The station in this latter work was three to four miles off Sydney and the temperature range was found to be approximately 7° C. This is very similar to the figures given by Lumby *(op. cit.)*.

Hedley points out that the Notonectian current swings off-shore in winter and on-shore in summer. This results in the appearance in summer of animals used to warmer seas. He further considers that the critical time for littoral organisms is low water spring tides (L.W.S.T.) on a winter night.

The tidal data given were very meagre and very little was done to correlate the data with the effects on the flora and fauna. This objection may be held for all the physical data given in the work.

The flora and fauna of Sydney were compared in a numerical sense with other places. The Mollusca replace the Crustacea as the dominant group, and the algae are poor and monotonous in comparison with the colder Northern Hemisphere seas. The migrations of the family Littorinidae from sea to shore are discussed and the zoning of this family in ascending order is given as *Bembicium melanostoma; Melaraphe acutispira; M. infans; M. mauritiana; Tectarius pyramidalis; M. scabra.*

The shingle beach is recorded as having no flora or fauna, while the ocean sand beach has a small fauna. The latter is mostly of burrowing carnivores. The muddy estuary is discussed and notes on the flora and fauna are given with some references to the forms growing on the species of mangrove. Some little attention is also devoted to the zosteretum and the fauna inhabiting it. Lagoons which have been formed by the damming of streams by heavy storms are described.

The ocean reefs are most fully covered in the paper. The surf is stated to be more heavy than in Europe and a zonation is given. In descending order this is as follows:—Upper Zone with *Tectarius* and *Melaraphe* and *Chthamalus* and *Tetraclita*. A Median zone with *Galeolaria* followed by a Lower *Cynthia* zone. *Hormosira* is present and forms a *Hormosiretum*. The various animals inhabiting the reefs are described and *Galeolaria* is noted as being intolerant of sand or mud. The *Galeolaria* habitat for other animals is mentioned.

Mussel beds are noted as not forming an important part of the shore fauna. Below tidal levels are the kelp beds. These are described in a very general fashion and a few of the forms living there are recorded.

As mentioned above, this paper might well have stimulated further interest in the littoral regions not only around Sydney but also in other parts of Australia. A possible reason for its not doing so lies in the tremendous taxonomic difficulties encountered in work of this nature.

(c) Ecological Notes on the Fauna and Flora of Caloundra, Queensland

Johnston, T. H. Queensland Naturalist II., 2, 1917, pp. 53-63

The habitats are those recognised by Hedley (1915). The zones described as occurring on the rocky coast are more numerous than those mentioned by Hedley. The author describes five zones, the first three of which correspond to the Upper zones of Hedley, while the last corresponds to the Lower zone of that author. The zones recognised are *Tectarius* at the top of the shore, followed in descending order by an Upper *Melaraphe* zone, a Lower *Melaraphe* or *Chthamalus* zone; *Tetraclita rosea-Liolophasa queenslandica* zone and at low water a *Sargassum-Ornithochiton* zone.

No consideration is given to the physical environment and most of the paper is devoted to lists of the plants and animals in the various habitats.

(d) Animal and Plant Communities of the Coastal Rock Platform at Long Reef, New South Wales

Pope, E. C. Proc. Linn. Soc., N.S.W., LXVIII., 5-6, 1943, pp. 221-54

The data given for the physical environment are intended to supplement those of Hedley (1915). Even with this addition the data are still weak, especially in relation to tides. The observations of sea temperatures taken on the reef over a considerable period throw some light on the differences between sea temperatures at several stations. The observations are summarised in a table. The greater variation in the temperatures at the reef than at other stations is attributed to the reef rock being affected by atmospheric temperatures.

The migrations of *Heliocidaris erithogrammus* and Nudibranchs are noted as being into shallow water in summer and *vice versa* in winter.

The nomenclature adopted shows only three major divisions of the shore. These are the Supralittoral above mean high water spring tides (M.H.W.S.T.), the Tidal from below M.H.W.S.T. to mean low water neap tides (M.L.W.N.T.) and the Sublittoral which is exposed at extreme low water spring tides (E.L.W.S.T.). The author points out that King and Russell (1909) noted the importance of the lower sides of stones as habitats. Each habitat is described as having a fauna and flora on the upper and lower surfaces, but the author does not consider the fauna in terms of the epibiose, hypobiose and endobiose of Gislén (1930).

The Supralittoral is not fully developed and the zoning of the Littorinidae is not apparent due to the lack of vertical height. The algae present are very poor and small in numbers and do not supply sufficient for the mollusca, which

points to the fact that there must be microscopic food available. The temperature range on the reef in this region is considerable. The fauna inhabiting the top and bottom of rock surfaces is described. The fauna below boulders in sand is also listed. On sand there is a belt of decaying plants and animals.

Most of the area studied is in the Littoral region. There are no plants in the upper part, though *Ectocarpus* appears seasonally. *Hormosira banksii* is dominant lower down the shore. *Corallina* is found at the lower limits of the littoral region. The animals of the region are of the mollusc-barnacle type (Clements and Shelford, 1939). They have spread so that it is difficult to find their limits. The distribution of the salient types is given and so is the zonation of the different groups. The lower rock surface fauna is described and classified as an *Ophionereis-Ischnochiton versicolor* community. The species inhabiting this are listed. The description of the littoral region concludes with notes on the small *Zostera* beds encountered and a list of fish and crustacea roving the reef at high tide.

The Sublittoral fringe is considered in some detail. The animals dwelling above and below rock surfaces are noted. These notes are of considerable interest and the various associations encountered in this region are discussed. The density of populations of certain species is also listed.

A most interesting feature of the part of coast which is described in the absence of the *Pyura praeputialis* association. This is attributed to the flatness of the reef and the shelter from fierce wave action. Some forms which are characteristic of still water are found, such as *Zostera*.

(e) A Zoological Sketch of Adelaide Beaches

Johnston, T. H., and Mawson, P. M. Handbook of South Australia. 25th Meeting, A.N.Z.A.A.S., Adelaide, 1946, pp. 42-7

This short paper contains notes on the different types of coast encountered near Adelaide. These are mangrove swamps, sandy mud, zosteretum, sandy flats, coastal jetties, sandy beach and rocky reefs. The forms inhabitating these habitats are listed.

On the reefs of the zones recognised are the Upper Littoral, Mid-Littoral, and Lower Littoral. The fauna and flora of these zones is then listed.

(f) Studies on the Marine Algae of South Australia. Part 1

The genera Isactis *Tjeoret and* Rivularia *C. Agardh.*

Womersley, H. B. S. Trans. Roy. Soc. S. Austr. 70, 1, 1946, pp. 127-136

This paper traces the history of phycology in Australia. The ecological notes are confined to those on distribution.

(g) Studies on the Marine Algae of South Australia. Part 2

Womersley, H. B. S. Trans. Roy. Soc. S. Austr. 70, 1, 1946, pp. 137-144

This paper contains a description of a new species of Dasyopsis and has no ecological notes.

(h) The Marine Algae of Kangaroo Island. Part 1

General Account of the Algal Ecology.

Womersley, H. B. S. Trans. Roy. Soc. S. Austr. 71, 2, 1947, pp. 228-252

The paper deals with four years' work and covers the physical environment. The general topographic features of the area are described and notes on the geology of the area are given.

The South and West coasts of the island are exposed and wave action is intense, and in the absence of any measurements of wave forces the alga *Cystophora intermedia* is taken as the index of heavy wave action.

The tides are of a semi-diurnal nature and exhibit diurnal inequality. There are no regular tidal records. The spring tide on the South coast is of some 2½ feet, but is 4 to 4½ feet elsewhere. Neap tides are 1½ feet to 2½ feet at similar places. Winter mean sea level is 4 inches to 6 inches above that of summer at Port Adelaide. The surface currents are those described in the Australia Pilot (1944).

The records of sea temperatures are not complete, but on-shore temperatures are given as varying between 13·5° C. and 19-20° C. The off-shore temperature was approximately 1° C. lower in summer than the on-shore figures. In the North of the island the off-shore temperature in summer was approximately 1° C. lower than the corresponding on-shore temperature. In winter the off-shore temperature was 1 to 2° warmer.

The air temperatures are fairly uniform throughout the year. The yearly average mean maximum temperature was 18·4° C. and the yearly average mean minimum temperature was 11·7° C. The average relative humidity was 76 per cent. Full tables of these records are given.

The salinity of the sea in the South is given as 35·4 to 35·9 grs./mille. (Cl = 19·6 to 19·9°/oo). The North coast has a slightly higher salinity of 37 grs./mille. The nitrate content of the sea is low, being less than $1/10^9$ and the phosphate varied from 14 to 23 p.p. 10^9. The pH, determined by colorimetric methods, varied from 8·2 to 8·3. The oxygen content varied from 110 per cent saturation during the day to 50-70 per cent at night.

The author recommends that littoral ecologists use terms which are suited to their own conditions and not try to follow the terms used by land ecologists. An association is defined as a grouping of organisms distinct in species composition and facies from another grouping.

The formations recognised are the rocky shore, sand and sandy mud, saltmarsh, vegetation of river mouths and the vegetation of brackish bays. The author does not recommend the use of formations based on dominants as they may be altered by migrations.

The Littoral zone is defined as extending from L.W.N.T. to the upper algal limit. The term Supralittoral is discarded and splash and spray used instead. The Sublittoral is described as extending from the lower limit of the Littoral zone down to the limit of algal vegetation. The Sublittoral fringe is to be regarded as a useful development of the Sublittoral in certain areas.

A general account of the algal ecology is given and the basic algal zonation has been worked out and is shown in a figure.

The rocky coast formation and the sandy and sandy mud formation each receive detailed attention and the various algal associations occurring in the different zones on the shore are described.

(i) A Study of Certain Aspects of the Ecology of the Intertidal Zone of the New South Wales Coast

Dakin, W. J., Bennett, I., and Pope, E. C. Austr. Jour. Sci. Res., Ser. B, I., No. 2, May, 1948, pp. 176-230

This article is concerned with the features of the New South Wales coast and the form of the basic zonation found thereon. Indicator types are named and discussed.

The sea temperature on the rocky coasts under consideration is taken as being similar to that found four miles out to sea from Sydney. This is rather surprising in view of the fact that one of the authors (Pope, 1943) showed that there was considerable variation between reef sea temperatures and open sea temperatures. The temperature differences of bays and enclosed waters varies very much. An enclosed bay with no fresh water contamination frequently shows a temperature in the summer which is 5° C. above that of the outer sea (Guiler, 1945). In lagoons, this difference is even greater (see later in this work). Hedley (1915) noted the effect of the on-shore swing of the Notonectian current in summer and, consequently, care would have to be taken that a current off-shore, in which the temperature observations were taken, was also running along the coast. There is no substitute for shore observations. The authors note that there is no satisfactory means of comparing the temperature of the ocean with that of pools until a record of shore sea temperatures is available.

The tidal range is greater than at Hobart. No data are available other than those for Sydney Harbour. There is little difference in tidal range between North and South New South Wales.

The coast of New South Wales is described by deduction as suffering rougher seas for longer periods than any other closely studied coast. This raises the levels of zones to greater heights and also alters the position of some species in exposed places, e.g., *Tetraclita purpurascens* Darwin may be found in the Melaraphe zone. *Pyura praeputialis* (Heller) doesn't alter its position with the exposure and so it may be used as an indicator species.

The nomenclature used shows four divisions of the coast, namely, the Supralittoral, Littoral, Littoral-Sublittoral fringe and the Sublittoral. The Littoral covers the intertidal region from H.W.S.T. to L.W.S.T. The Supralittoral is the zone above the Littoral and is mostly inhabited by Littorinids. The Sublittoral is covered at all times. The Littoral-Sublittoral fringe is very sharply differentiated and is exposed at very low tides. It is marked by *Phyllospora* and *Ecklonia*, and is described as definitely intertidal, especially in sheltered places. At the margin of the Littoral and Sublittoral is found *Pyura praeputialis* (Heller).

The zones are then discussed in detail. The Littoral-Sublittoral fringe is characterised by *Pyura praeputialis* (Heller), which is described as liking rough, open water. The range of this species is from 28° S. to 38° N. Above this species there is found *Galeolaria caespitosa* Lam. This species occurs isolated or in tube masses up to 8 inches thick. At Fort Denison it is found about 2 feet above zero tide mark and 1 foot in depth. Under certain conditions this may be altered. In the tube masses there are many small animals, notably *Ibla quadrivalvis*, *Onchidium patelloides*, *Lasaea australis*, *Desis crosslandi* and a flatworm. This zone is absent in South Africa, though it is represented by *Hermella* in New Zealand.

The lowest of the barnacle zones is that of *Chamaesipho columna*. This species occurs at a density of 3000 per square foot. It is replaced by *Chthamalus antennatus*. Where surf is heaviest, *Catophragmus polymerus* and *Tetraclita rosea* are found. The latter occurs up to 2 feet above high water, due to the spray effects. The sequence of zonation of the Balanoid zone is summed up below.

Exposed Coast	Sheltered Rocks
Chamaesipho-Chthamalus	*Chthamalus*
Tetraclita	*Chamaesipho*
Catophragmus-Tetraclita	
Galeolaria	*Galeolaria*

There also occurs a community of limpets on vertical, moist upper rocks.

In the Supralittoral *Melaraphe unifasciata* and *Nodilittorina* are characteristic. The latter species is found up to 40 feet above sea level.

The geographic range of the basic associations shows very little change. Only nine animal and two algal species disappear in the stretch of coast under consideration.

The animals living in the various associations are then listed and notes describing them are given.

(j) The Commoner Species of Animals and their Distribution on an Intertidal Platform at Pennington Bay, Kangaroo Island, South Australia

Edmonds, S. J. Trans. Roy. Soc. S. Austr. 72, 1, 1948, pp. 167-177

The author gives a brief description of the reef, but refers the reader to Womersley (1948). The wave action on the platform at high tide is described as strong. The substratum is of rock and most animals live firmly attached to rocks or algae.

For a description of the physical environment, reference is given to Womersley (1947 and 1948). The reef temperature is stated as being within 1° C. of the sea temperature. The latter varies between 19° C. in summer and 13·5° C. in winter. The salinity is variable between 35·2 grs./mille. and 35·4 grs./mille. The pH varies between 8·2 and 8·3.

The terms Supralittoral, Littoral and Sublittoral fringe are used to designate the regions of the shore. The author follows Cranwell and Moore (1938) and Oliver (1923) and considers the littoral zone to be from the highest wash of the waves to L.W.S.T. The Supralittoral is the spray zone and the Sublittoral fringe is the narrow region exposed at very low tides. The average height of H.W.S.T. is described as impossible to determine due to the small range of tides at Kangaroo Island. Hence the classification adopted by Pope (1943) cannot be used.

The Supralittoral is populated by *Melaraphe unifasciata* with a *Lichina* sp. and *Nodilittorina tuberculata* above it. Pools in this region have been found to have a temperature of 35° C. and a salinity of 40·2 grs./mille. with *Melaraphe unifasciata, Bembicium melanostomum, Galeolaria caespitosa* and *Siphonaria* sps. living in them.

The Littoral comprises most of the reef and consists of a vertical cliff face and the platform. The latter is of two levels and is penetrated by a channel.

The cliff face animals are barnacles, serpulids and molluscs. The zoning of the barnacles from the top of the shore is *Chthamalus antennatus, Chthamalus* + *Chamaeosipho columna, Tetraclita purpurascens*; *Catophragmus polymerus* occurs in exposed surf with a few *Balanus nigrescens.*

The molluscs form two bands, an upper *Notoacmaea-Siphonaria* type band and a lower *Modiolus pulex (?Brachyodontes rostratus)* band. The zonation of the upper band has not been determined with satisfaction, but notes on the forms living in the lower are given.

Four algal associations are found on the rock platform. These are *Cystophyllum muricatum* association, *Cystophora* complex, *Hormosira banksii* and a *Cystophora-Corallina* association. These algal associations have characteristic weed feeding molluscs. A list is given of the Gasteropods, starfish, chitons and other animals found living there.

The Sublittoral fringe was rarely examined. In 4 or 5 square yards there were encountered 40 to 50 algal species. The commonest animal is *Boltenia australis*. There is no *Pyura praeputialis* bed similar to that found in N.S.W.

A table of densities of animals per 0·5 metre square is given, as well as a list of species.

(k) The Marine Algae of Kangaroo Island, II. The Pennington Bay Region

Womersley, H. B. S. Trans. Roy. Soc. S. Austr. 72, 1, 1948, pp. 134-66

This paper is a continuation of the work described in Womersley (1947), being the study of the algal ecology of one area. The substratum is composed of reefs of horizontally wave cut platforms of calcareous sandstone with a vertical drop at their edge into water 10 or more feet in depth.

The tidal range is 2½ feet at springs and 1½ feet at neaps. Winds can considerably modify the tidal range. The outer parts of the reef are always rough, but with a West wind and a calm sea the waves are only 1 to 2 feet in height. Most of the reef is washed by small waves.

The temperatures on the reef are within 1° C. of the sea temperatures. The range of variation of sea temperatures is from 13·5° C. in July to 19° C. in January. Pools may reach 30° C. in summer. Summer air temperatures of 37° C. with a North wind and low tides are important to the ecology of algae. No harmful winter effects have been noted. The prevalent winds are South to West. The Cl is 19·5 to 19·6°/oo, with little annual change expected. The pH of the sea varies from 8·2 to 8·3.

The small tides and heavy wave action give no marked horizontal zones, but algal zones do occur, a change of 2 inches or 3 inches in reef level causes profound alterations in algal associations.

All the reef lies in the Littoral zone. Due to the conformation of the reef few of the algae are ever completely exposed. It is only at the Rearlittoral that the algae are exposed for any length of time.

A *Prasiola* community is the only algal community which is Supralittoral and it is only found where penguin colonies occur.

The various algal associations are described in full and biocenoses of *Symploca hydnoides* with *Tetraclita purpurascens* and *Gelidium pusillum* and *Galeolaria caespitosa* are described.

The zones recognised are the Supralittoral. Littoral, Sublittoral fringe and the Sublittoral. The Littoral is further considered as the Rearlittoral and the Littoral.

Seasonal variations in the algal flora are noted and discussed. Observations are also made on the variations under wave action, parasitism, epiphytism and the vertical distribution in relation to the intensity of light.

Part III.—The Physical Environment

(a) The Tides

(1) In the South of Tasmania

The only available records of the tides in the South of the Island are those made by the automatic recorder maintained by the Marine Board of Hobart. This apparatus is situated on one of the piers at the port of Hobart. By courtesy of the Harbourmaster, Captain Bowerman, I have had access to the readings of the recorder and have taken records over a period of twelve months from the beginning of November, 1947, until the end of October, 1948.

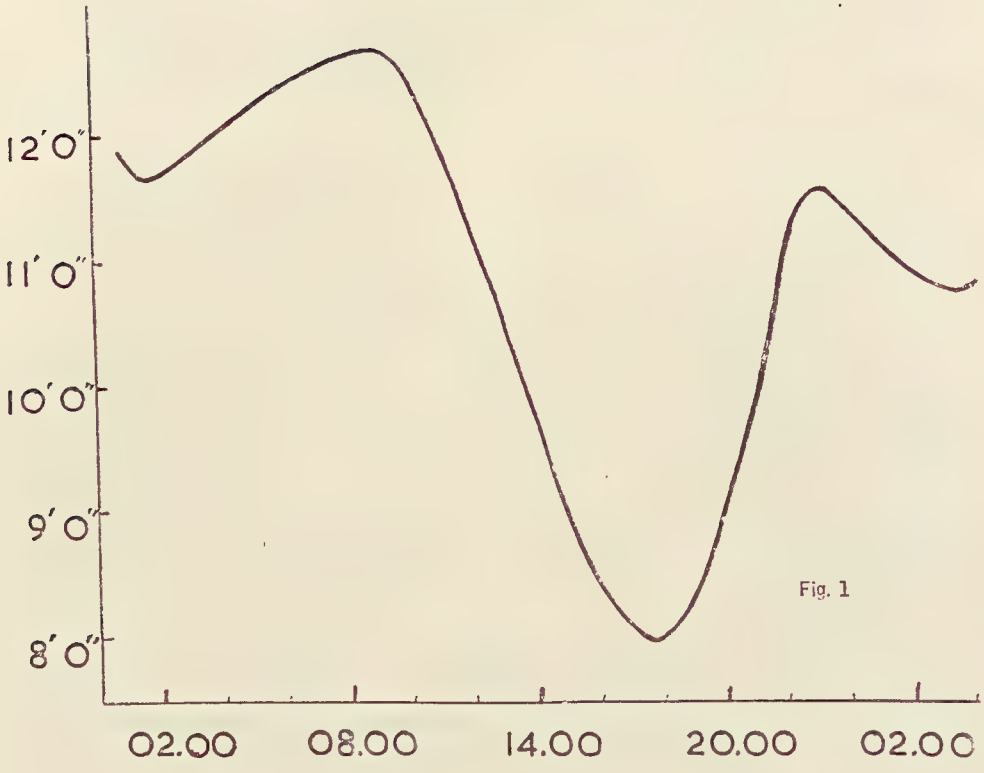

Fig. 1

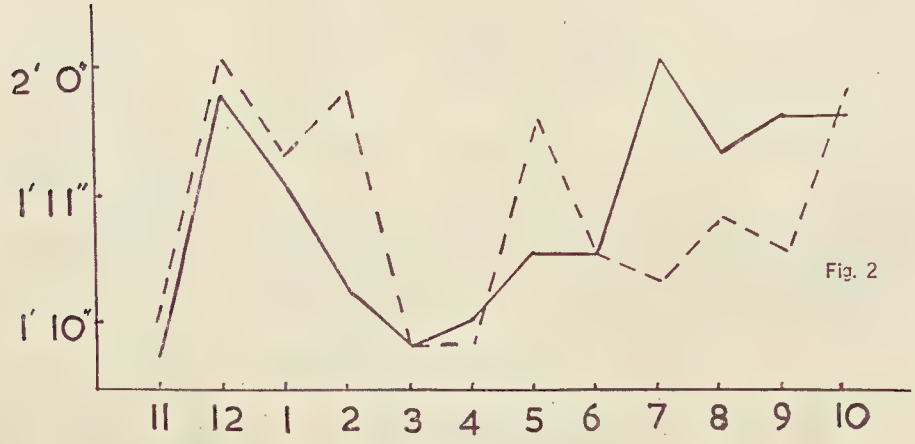

Fig. 2

FIG. 1.—Tidal curve from 01.00 hrs., 30th December, 1947, to 04.00 hrs., 31 December, 1947. The record is taken from the trace of the automatic recorder at Hobart. The figures indicating the heights of the tides have not been altered from those on the recorder for reasons stated later in the text.

FIG. 2.—The average monthly rise and fall of the tides over the period November, 1947, to October, 1948. The unbroken line represents the fall while the broken line shows the rise.

The tides at Hobart are of the semi-diurnal type common to the Australian coasts. Figure 1 shows a typical tidal curve for a 28-hour period. This curve has been modified from the trace of the recorder. It will be seen that there occur during this period one very high tide and one very low tide and three tides the heights of which are very similar. Of these latter tides high and low tides can be differentiated. I propose to follow Chapman (1938) and call these tides 'high high', 'low low', 'low high', and 'high low' respectively. The term 'dodger' is used for the latter tides in many places when for a considerable period the tide gives the appearance of remaining nearly full.

Chapman (1938) discusses the different theories of the origin and prediction of Australian tides and points out that the only feasible method of explaining or predicting the tides is by harmonic analysis. Unfortunately, this has never been attempted successfully for Hobart. There are three probable reasons for this failure. The first reason lies in the smallness of the tidal range and the consequent relative amount of correction to be applied for such factors as change of barometric pressure, prevailing wind, &c. Another reason is the lack of economic necessity for such an accurate prediction. Due to the depth of water in the harbour, a difference of a few feet is of little importance. The third reason lies in the fact that there is a double entry for the tides at Hobart. It is unfortunate that the recorder is situated in a position where it shows this inaccuracy. The first entry is across Storm Bay and straight up the estuary of the River Derwent, while the second entry is up D'Entrecasteaux Channel and so into the estuary of the river. The traces of high water frequently show two high waters which may be over an hour part though the average is less than 45 minutes. The second wave from the Channel supplements the first and gives the reading which is used in this work.

The greatest rise noted for the period under consideration was 3 feet 6 inches on the 2nd December, 1947, the average rise for the year being 1 foot 10 inches, and the minimum rise was ½ inch on the 4th May, 1948. The greatest fall noted was 5 feet on the 8th July, 1948. The average fall for the year was 1 foot 11½ inches and the minimum fall was 0 inches on the 9th January, 1948. Figure 2 and Table I show the average rise and fall.

TABLE I

Monthly average rise of tide, fall of tide, and rise and fall of tides for the period November, 1947, to October, 1948.

	Rise of Tide	Fall of Tide	Rise and Fall of tide/2
November, 1947	1′ 10″	1′ 9¾″	1′ 10″
December, 1947	2′ 0″	1′ 11¾″	2′ 0″
January, 1948	1′ 11¼″	1′ 11″	1′ 11″
February, 1948	1′ 11⅝″	1′ 10¼″	1′ 11″
March, 1948	1′ 9¾″	1′ 9¾″	1′ 9¾″
April, 1948	1′ 9¾″	1′ 10″	1′ 10″
May, 1948	1′ 11½″	1′ 10½″	1′ 11″
June, 1948	1′ 10½″	1′ 10½″	1′ 10½″
July, 1948	1′ 10¼″	2′ 0″	1′ 11″
August, 1948	1′ 10¾″	1′ 11¼″	1′ 11″
September, 1948	1′ 10½″	1′ 11¼″	1′ 10¾″
October, 1948	1′ 11½″	1′ 11½″	1′ 11½″

The tides exhibit diurnal inequality of both high and low tides. In figure 1 the morning tides are higher than the afternoon tides, due to the position of the sun being South of the Equator. Figure 3 shows the reverse when the sun is North of the Equator. The change over from one condition to the other takes place about the equinoxes. In 1948 the changes took place on 22nd April and the

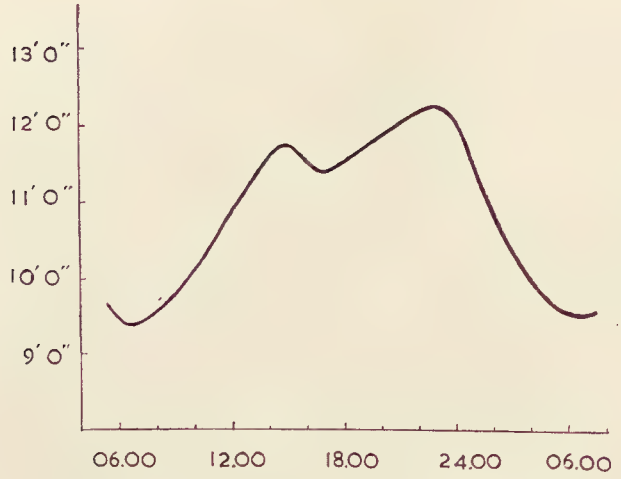

FIG. 3.—Tidal curve for the period 06.00 hrs. 26th June, 1948, to 06.30 hrs., 27th June, 1948. The curve is smoothed from the trace on the Hobart recorder. The heights of the tides are also those shown on the recorder.

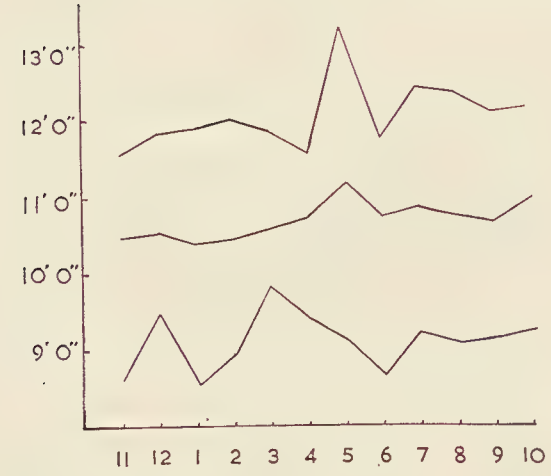

FIG. 4.—The average monthly heights of the tides for the period November, 1947, to October, 1948. The upper, middle, and lower lines represent the 'high high', 'high low + low high/2', and 'low low' tides respectively. The figures for the tidal heights are those of the Hobart recorder.

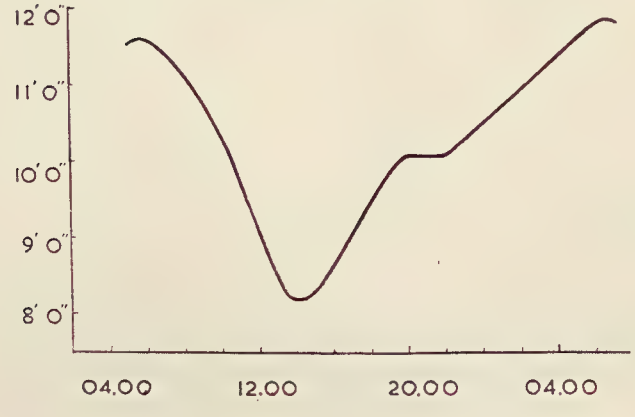

FIG. 5.—Tidal curve from 04.00 hrs., 9th January, 1948, to 08.00 hrs., 10th January, 1948. The curve is smoothed from that of the Hobart recorder and the tidal heights are those shown on that apparatus. The tide on this date showed complete suppression of the 'high low' tide.

27th October. The April change was foreshadowed by very great irregularity of the tides dating from the 28th March. From that date until the 22nd April the morning tide was larger than the afternoon for several days. Then the afternoon tide became dominant for a few days. There was no such disturbance at the October change.

As regards general behaviour, the tides act in a similar manner to those described for Port Adelaide by Chapman (1938). Due to the absence of an analysis and the great effects of the wind, barometric pressure and the double tidal entry, it is difficult to get a true picture of the effects of the various tidal components. For that reason the following remarks and those in Part V. of this work refer only to the recorded tides.

At neaps there is frequently a single fall in the tide in a 24-hour period, probably due to the reduction of the M and S elements. Figure 5 shows a modification of this condition in that the ascending afternoon curve is flattened out to give the negative rise or fall mentioned above on the 8th January, 1948. It must be noted that a single low tide in a day does not necessarily mean that it is an extreme neap tide. Single low tides occurred on the 16th November, 1947, and on the 19th of the same month. At neaps the time of the tide is very irregular. On the 17th November, 1947, the times of the tides were L.H.W 01.00 hrs.; H.L.W. 04.15 hrs.; H.H.W. 09.00 hrs.; L.L.W. 18.30 hrs. On the 2nd December, 1947, the times of the tides were H.L.W. 02.30 hrs.; H.H.W. 09.30 hrs.; L.L.W. 18.30 hrs. At springs there is very little difference between 'low high' and 'high low' tides. On the 8th July, 1948, the difference was 3 inches. In that month the average fall of the tide was two feet. The monthly heights of the tides are shown in Fig. 4 and Table II.

TABLE II

Mean Sea Level for the period November, 1947, to October, 1948.

November, 1947	10′ 4½″	May, 1948	11′ 1½″
December, 1947	10′ 7″	June, 1948	10′ 5¼″
January, 1948	10′ 4½″	July, 1948	10′ 9″
February, 1948	10′ 5½″	August, 1948	10′ 8½″
March, 1948	10′ 6″	September, 1948	10′ 7¾″
April, 1948	10′ 5¾″	October, 1948	10′ 9½″

Mean Sea Level for the twelve months, 10′ 7¼″.

The time interval separating the tides may be regular or irregular, irrespective of the phase of the moon. On the 7th June, 1948, the times of the tides were very irregular. L.L.W. 01.00 hrs.; L.H.W. 07.00 hrs.; H.L.W. 12.30 hrs.; H.H.W. 19.40 hrs., while on the following day the times for the corresponding tides were 03.00 hrs.; 11.30 hrs.; 13.00 hrs. and 20.30 hrs. respectively. The 'low high' and 'high low' tides are nearly always irregular in the time of their occurrence. These irregularities are probably due to non-lunar and non-solar influences. (Fig. 5 also illustrates this irregularity.)

The method used for the prediction of the tides is the 'establishment', which at Hobart is 08.15. This is subject to numerous inaccuracies and is of very little use in planning shore collecting trips.

(2) The Tides in the North of Tasmania

Tidal records are available at Launceston where there is an automatic recorder maintained by the authorities of that port. The tides in this part of Tasmania will be considered at a future date in connection with the survey of the North of the Island.

(b) Climatic Factors.

(1) Relative Humidity

The mean monthly relative humidity over the period November, 1947, to October, 1948, shows a series of sharp monthly differences (figure 6). A rise in the index for the period November-December was followed by a drop in January with a sharp rise again in February. In March the index fell to the November figure (61 per cent), but rose again in April. The highest figure was in June, and from that month until September there was a gradual fall in the relative humidity, but in October it rose again. For these figures, on which this graph is based, I am indebted to the Weather Bureau, Hobart.

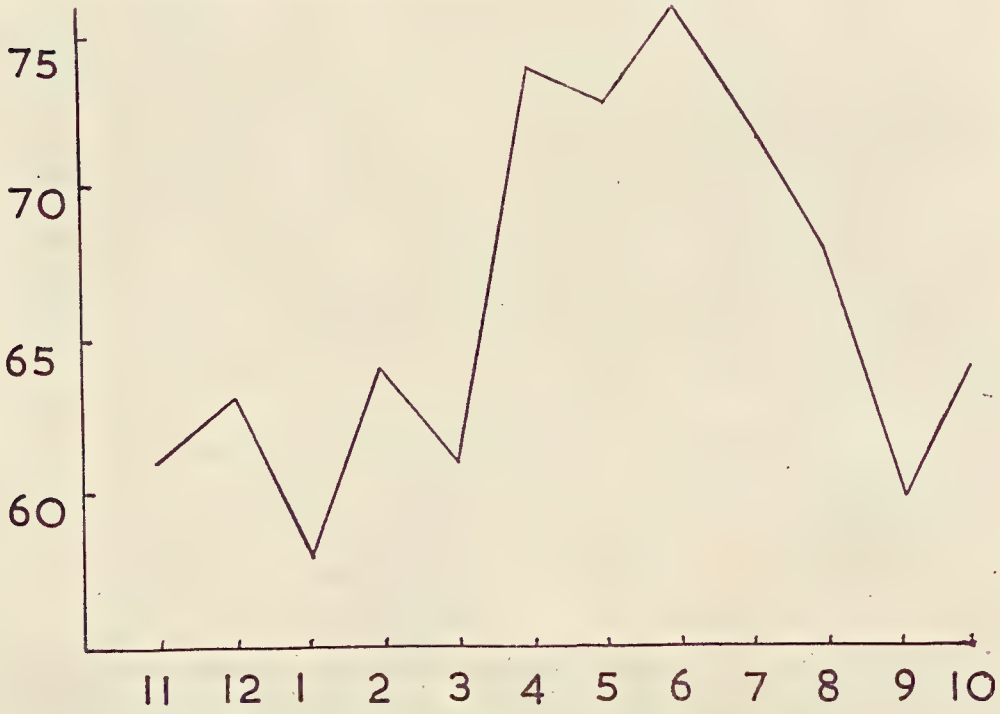

FIG. 6.—Mean monthly relative humidity at Hobart for the period November, 1947, to October, 1948. Data supplied by the Weather Bureau, Hobart.

(2) Barometric Pressure

The mean monthly barometric pressure has been calculated from the mean daily reading, which is one-half of the sum of the readings taken at 09.00 hrs. and 15.00 hrs. I am indebted to the Weather Bureau, Hobart, for these figures. The period for which the figures were obtained was November, 1947, to October, 1948. Over this period the lowest monthly average was recorded in October, 1948, although the minimum recording for that month was considerably above that for the preceding month. In September, the lowest average monthly minimum reading was recorded. The highest mean monthly minimum was recorded in April, 1948 (figure 7).

The highest mean monthly average pressure was recorded in June, 1948, while the lowest was recorded in October, 1948. The former does not correspond

with either the maximum mean monthly minimum or the maximum mean monthly maximum. The lowest mean monthly maximum was recorded in October, 1948, and the highest mean monthly minimum was recorded in July, 1948.

The fluctuation in the mean monthly average pressure from November, 1947, to October, 1948, was largely due to the effect of a varying mean monthly minimum pressure as the mean monthly maximum was fairly constant throughout this period. From April, 1948, until October of the same year the mean monthly average pressure followed a similar pattern to that of the mean monthly maximum and minimum pressures.

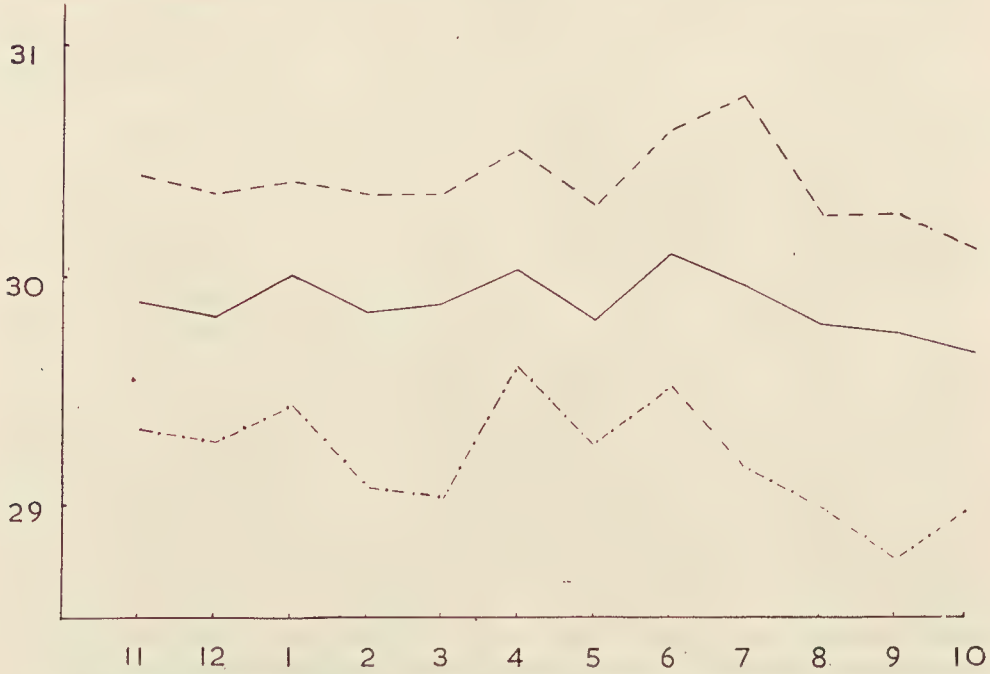

FIG. 7.—Monthly barometric pressure at Hobart for the period November, 1947, to October, 1948. The upper, middle, and lower curves show the mean monthly maximum, mean monthly average, and mean monthly minimum pressures respectively. The mean monthly average pressure is based on the average of daily readings at 09.00 hrs. and 15.00 hrs. Data supplied by the Weather Bureau, Hobart. The pressure is in inches of mercury.

(3) Wind

The prevailing winds in Southern Tasmania are Northerlies and North-Westerlies. These winds usually are warm and in summer can be hot and must have a considerable desiccating effect of the littoral fauna.

During the summer a local Southerly wind springs up usually around mid-day. This wind is cold and can be fairly strong and gives rise to short steep waves. As noted above, the East shore of the Estuary does not suffer to the same extent as the West from these local seas.

(4) Air Temperatures

The mean monthly air temperatures for the period November, 1947, to October, 1948, are shown in figure 8. I am indebted to the Weather Bureau, Hobart, for these figures. There is a fairly close correlation between the mean monthly

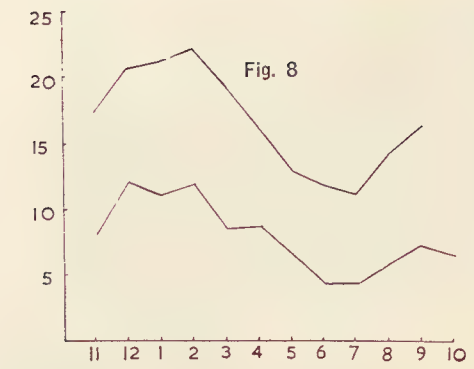

Fig. 8

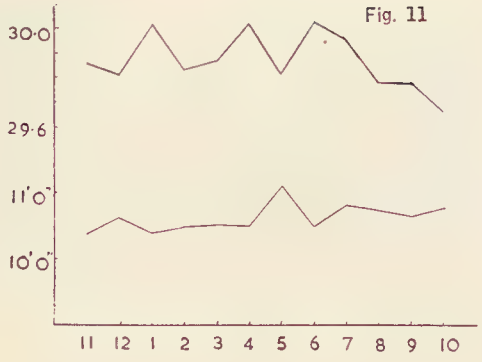

Fig. 11

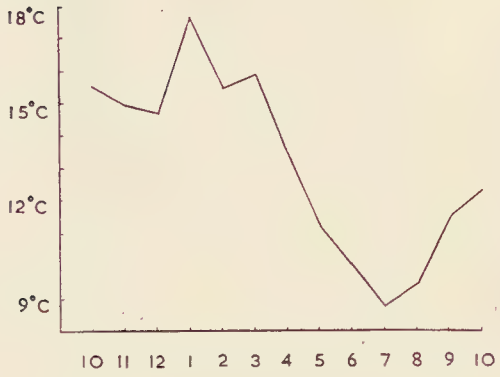

Fig. 9

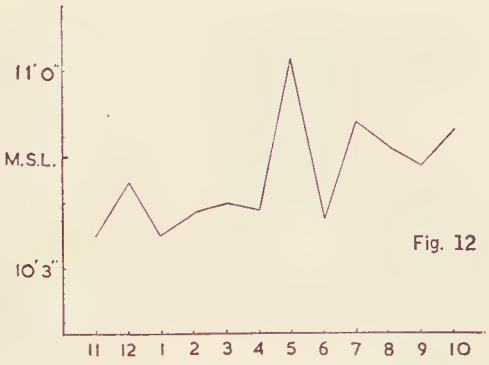

Fig. 12

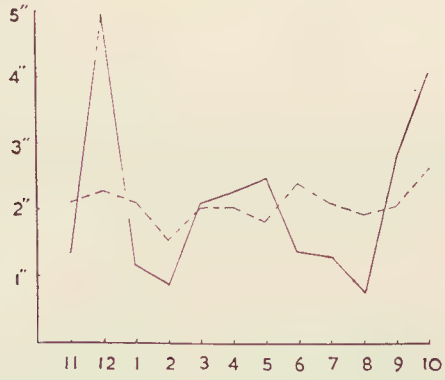

Fig. 10

FIG. 8.—Mean monthly maximum and minimum air temperature at Hobart. The temperature is in degrees Centigrade. Data for Hobart supplied by the Weather Bureau. The period of observation was November, 1947, to October, 1948.

FIG. 9.—Mean monthly sea temperatures at Hobart for the period October, 1948, to October, 1949. The temperature is in degrees Centigrade and was taken at Station 37, Derwent Estuary.

FIG. 10.—Rainfall at Hobart for the period November, 1947, to October, 1948. The continuous curve shows the actual rainfall while the broken line shows the average rainfall over the last 66 years. Data supplied by the Weather Bureau, Hobart.

FIG. 11.—Relation between the height of Mean Sea Level and the barometric pressure. The period under consideration is November, 1947, to October, 1948. The height of M.S.L. is expressed in recorder datum (R.D.) and the barometric pressure in inches of mercury.

FIG. 12.—Variations in the monthly levels of M.S.L., Hobart, for the period November, 1947, to October, 1948. Heights in R.D.

maximum and the mean monthly minimum temperatures. In April, 1947, this correlation breaks down slightly, the minimum temperature for that month being slightly above that of the preceding month, although the general trend of the graph at that period is downwards.

The maximum monthly air temperature was recorded in February, 1948 (21·83° C.), and the minimum in August, 1948 (4·11° C.). The minimum maximum monthly temperature was 10·94° C. in July and the maximum minimum monthly temperature was 11·94° C. in February.

During the period under consideration, the absolute maximum temperature recorded at Hobart was 35·26° C. and the minimum temperature was —4·4° C. These temperatures were recorded on the 12th February and the 18th August respectively.

(5) Sea Temperatures

There are no available records for the temperature of off-shore sea waters in Tasmania. This is a great lack in view of the interesting comparisons between on-shore, reef and off-shore water temperatures given by Pope (1943).

The figures which have been graphed in figure 9 were compiled by the author for purely on-shore waters. The station at which the records were made is at the seaward end of a small concrete outfall of a small creek at the Sandy Bay site of the University. This is Derwent hydrological Station No. 37. There are several objections to this station. The first is that the readings taken there will be subject to serious error due to fresh water contamination. To a large extent this has been reduced by taking the temperature at the extreme seaward end of the outfall and at a point where there was a minimum of fresh water. The flow down the creek is very small, except at times of heavy rains. It may be said that the error is only present at a time of very wet weather. A further objection is that the sea at this station is shallow and at 'low low' water an area of sandy mud is exposed. A flow tide on a warm or cold day will be affected to some degree by this flat stretch of sand. To some extent this error was eliminated by taking the temperature before 10.00 hrs., by which time the sand was not warmed very much by the sun. There was no satisfactory method of eliminating the error for cold water other than by taking the readings at high water. It might be pointed out that these errors are not very serious as usually 'low low' tides were avoided during the observations.

The range of temperatures is from 8·8° C. for July, 1949, to a maximum of 17·6° C. in January of the same year. The period of observation was from October, 1948, to October, 1949 (Table III). The extremes of temperature recorded were 19° C. on 2nd January, 1949, and a minimum of 6·3° C. on 22nd July, 1949.

TABLE III

Sea temperatures at Hobart from the period October, 1948, to October, 1949, recorded at Station 37, River Derwent.

	Temperature (°C)		Temperature (°C)
October, 1948	15.5	April, 1949	13.4
November, 1948	14.9	May, 1949	11.2
December, 1948	14.7	June, 1949	9.9
January, 1949	17.6	July, 1949	8.8
February, 1949	15.4	August, 1949	9.5
March, 1949	15.8	September, 1949	11.5
		October, 1949	12.3

Further observations on the temperature of the sea will be given in a later part of this work.

(6) Salinity and other Chemical Factors

The salinity and other chemical factors will be discussed at some length in the Derwent hydrological survey. It is sufficient to state here that the salinity varies around 34·8 grs./mille. for open sea. The figure for the estuary of the Derwent is very variable and much lower than that quoted above for open sea.

(7) Insolation and Light Intensity

It is not possible to obtain accurate details as to the amount of insolation to which littoral organisms are exposed in Tasmania. One of the features of summer weather in Hobart is the sea breeze which springs up about mid-day. As well as being a cold wind, this change brings cloud on Mount Wellington, especially on the Southern aspect. This cloud has the effect of casting shadow over certain parts of the coast and Hobart so that figures given for sun-hours in Hobart need not necessarily apply for more than three miles from Hobart where the recording station is situated.

The light intensities to which littoral organisms are subjected vary considerably with the habitat favoured by the organism. The intensities of light in various habitats will be considered in the sections of this work dealing with the detailed ecology of restricted areas.

(8) Currents

Not sufficient is known about the influence of currents on the littoral fauna of Tasmania. The detailed behaviour of the currents has not been fully studied. The sudden drop in sea temperatures in June and the equally sudden rise in September might suggest that either a warm current leaves Tasmanian waters in June or that a cold one arrives. The converse might be happening in September.

(9) Rainfall

Over a period of 66 years for which records are available at Hobart the rainfall averages about 2 inches per month. Figures for the average rainfall and for the period November, 1947, to October, 1948, were obtained from the Weather Bureau, Hobart (figure 10).

The month of February is 0·6″ below this average and must be considered to be the driest month of the year. August and February are the two driest months, while December is the wettest.

(c) Geological Features

It is not proposed to enter into the details of the geology of the coastal areas of Southern Tasmania. A large proportion of the areas studied have been composed of mudstone. The mudstone frequently weathers into wave platforms. Dolerite is found in places on the coast. By contrast, this latter rock usually does not weather into platforms. Full details of the geology of the Hobart area can be found in Carey and Banks (1949).

In any future parts of this work where it is necessary to describe the geological features of a region a brief description of these will be given at the beginning of that part.

Discussion

The physical environment as far as it has been described above may be compared with that of other parts of Australia. The comparisons are not complete due to the lack of much data in both Tasmania and the mainland States.

The tides in South Tasmania are considerably smaller than those which have been described by several ecological workers as prevailing in the Sydney area. This remark does not apply to the tides in the North of Tasmania, which have a much greater rise and fall than those in the South. There have been no detailed figures published relating to tidal data for the Sydney area. Hedley (1915) was very vague on the subject and Dakin and Colefax (1940), Pope (1943) and Dakin, Bennett and Pope (1948) all state that the tidal range is about 3 to 4 feet with extremes of about 6 feet at springs. Chapman (1938) does give some figures for New South Wales, but these are not sufficient to warrant any ecological conclusions. It is obvious, however, that the tides at Hobart are much less in magnitude than are those at Sydney.

The tides at Kangaroo Island are of a similar magnitude to Hobart tides (Chapman, 1938, and Womersley, 1947). In general behaviour the tides at Hobart are like those at Port Adelaide (Chapman, *loc. cit.*).

The mean monthly sea temperatures at Hobart, subject to the errors and conditions given in section 5 above, have a range of 7·8° C. This is similar to the range found for surface off-shore waters at Sydney by Dakin and Colefax (1940). On the other hand, the temperatures within this range at Hobart are very much colder than at Sydney. The average temperature for February, 1932, at the latter place was 23° C. The absolute maximum recorded over a 12-month period at Hobart on 2nd January, 1948, was 19° C. The Hobart absolute minimum is well below the corresponding Sydney figures. There are no off-shore temperature figures available for Tasmania.

The average relative humidity at Hobart is appreciably less than at Kangaroo Island, Womersley giving 76 as an average annual figure at that place. while the Hobart annual average is about 68.

The mean air temperatures are cooler that at Sydney or Kangaroo Island. The Hobart annual average maximum and minimum temperatures are less than those at Kangaroo Island by 2° C. and 5° C. respectively.

Figure 11 shows the relation between the variations in Mean Sea Level (M.S.L.) and the barometric pressure. An increase in the average monthly barometric pressure is reflected by a corresponding decrease in the level of M.S.L. (Table IV and Fig. 12).

TABLE IV

Variations in Mean Sea Level (M.S.L.) for the period November, 1947, to October, 1948. M.S.L. calculated from the traces of the Hobart automatic recorder.

November, 1947	10′ 4½″	May, 1948	11′ 1½″
December, 1947	10′ 7″	June, 1948	10′ 5½″
January, 1948	10′ 4½″	July, 1948	10′ 9⅜″
February, 1948	10′ 5½″	August, 1948	10′ 8½″
March, 1948	10′ 6″	September, 1948	10′ 7⅜″
April, 1948	10′ 5⅜″	October, 1948	10′ 9½″

Mean Sea Level for the twelve months, 10′ 7¼″.

PART IV.—THE TIDES AS AN ECOLOGICAL FACTOR

(a) Introduction

In view of the important work on tidal exposures at different levels of the shore which has been carried out in various overseas countries, it is surprising that no comparable efforts have been made in Australia. As is obvious from the literature reviewed in Part II of this work, the tides in many cases have received only passing attention. The lack of study of the tides may be explained in part

by the until recently undeveloped state of littoral ecology in Australia. The lack of tidal data over large areas of the coast serves as a further deterrent to work of this nature.

The conclusions formulated in this discussion of tidal phenomena must be regarded as local in application. The tides in Northern Tasmania are of much greater magnitude than those in the South and therefore require separate treatment. The results must further be regarded as approximate, even for the local area to which they apply. The reason for this lies in the fact, as outlined in the section on tides, that the Hobart recorder is subject to 'estuarine inaccuracies' such as wind, &c. The double entry of the tides is another source of inaccuracy.

It is necessary to note that the statement made by Colman (1933) that the ecological tidal level is not that shown on the recorder, but that reached by the surf, is especially valid on the exposed and semi-exposed coasts of Tasmania where, even in summer, choppy seas are frequently encountered.

(b) Literature

As mentioned above, there is no Australian literature on this aspect of littoral ecology.

The pioneer work on the effect of exposure on littoral organisms is that of Colman (1933). This author stressed the importance of 'critical' levels. The number of species appearing at different levels of the shore was considered in relation to the percentage exposure they suffered. It was found that for sedentary species critical levels existed between M.S.T. and E.L.W.S.T. (5 per cent exposed per annum); between M.L.W.N.T. and M.L.W.S.T. (20 per cent exposed per annum) and at E.H.W.N.T. (60 per cent exposed per annum).

It was realised before the work of Colman that exposure controlled algal distribution on the shore. For example, Johnston and York (1915) stated 'the vertical distribution of littoral algae depends on the period of emergence and submergence'. It was Colman who first considered this factor quantitatively.

Grubb (1936) using the technique of Colman found that each algal species at Peveril Point, Dorset, has 'a definite range of exposure above or below which it does not flourish successfully'. The vertical distribution of various algae was plotted against the exposure curve and a very close similarity to Colman's results was found.

Zanefeld (1937) working in Holland found that the tidal levels of algae at several localities were very similar. In passing it is worth noting that the numerous levels into which Zanefeld split the tidal region are not practicable in Tasmania due to the small tidal range. The factors controlling the desiccation of algae were analysed. In general it was shown that the higher up the shore a species grows the greater is the water loss but the slower the rate. Also, long exposed species have a higher fat content and a thicker cell wall than those species which are not exposed for long periods.

David (1941), working at Aberystwyth, found four critical levels only one of which was the same as any of those found by Colman. The levels found by David were at M.H.W.S.T.; M.H.W.N.T.; E.(L.)H.W.N.T. and E.(H.)H.W.N.T.

It is not proposed to give detailed accounts of the numerous papers published on littoral algae and the factors governing their distribution. A review of this aspect of ecology is given by Chapman (1941).

Several other workers have used the exposure method of approach to littoral problems and in each case the exposure curve obtained is very similar to that of Colman (e.g., Evans, 1947*a*, and 1947*b*).

Doty (1946) was among the first to apply this technique to tides exhibiting diurnal inequality. The form of the curve obtained is similar to that of Colman but differs in that the exposure increased more rapidly at certain levels of the shore. The station at which the tidal records were made was the entrance to San Francisco Bay where the tidal range is much greater than at Hobart. The terms used to designate the different tides were those of the U.S. Coast and Geodetic Survey. There were 6 or 7 zones on the shore but sudden increases in exposure were found to occur at 3 feet 5 inches, three feet and one foot above chart datum. Doty further noted that M.S.L. is varied in height on the shore by wind action. He pointed out that 'variation in vertical distribution seems to be correlated with daily, monthly or annual variations in the levels at which the tidal phenomena occur and with variations in the time the algae reproduce, after account is taken of the local topography'.

(c) Exposure at Hobart

The general behaviour of the tides at Hobart has been described above (Part IV).

The method used in obtaining the exposure factor may be described here. Using the figures obtained from the automatic recorder in Hobart, the average exposure at different levels of the shore was obtained for each month of a year. The period for which the tides were studied was from November, 1947, to October, 1948. The method used by Colman (1933) was not employed mainly for the reason that the smallness of the range of tides makes it impossible to determine whether a tide, say the H.W.S.T., is a true H.W.S.T. or one that has become depressed or supplemented by changes in barometric pressure, wind or other local effects. Admittedly we are concerned with the actual tide and not the theoretical tides, but in view of the likelihood of considerable error in using a few tides for analysis, I consider it advisable to use the average of the tides for a month. The dominant factor in considering tides in Tasmania is that the mean tidal range is only 1 foot 10 inches so that a tide supplemented by local effects by 4 inches represents a considerable percentage error. Local effects of 6 inches are common.

Mean sea level fluctuates considerably (figure 12). The relation between the variations in M.S.L. and barometric pressure has been noted above (figure 11). It is not suggested that barometric pressure is the sole factor responsible for the fluctuations of M.S.L., but it is probably the major factor.

Considerable difficulty has been experienced in reducing the tidal data to some fixed base line. Chart datum (C.D.) for Hobart is 'approximately Indian Low Springs'. M.S.L. is noted on the charts as being 3¼ feet above C.D. (Admiralty, 1944). Subtraction of this figure from the observed M.S.L. gives a level for L.W.S.T. which is never less than 5 inches below the minimum extreme reading of spring tides for that particular month. At equinoctial springs in 1948 the error was in the magnitude of 9 inches. The effect of this is that the C.D. cannot be used in a satisfactory fashion as a tidal constant since the extreme low spring tides cannot be shown as a negative tide.

In the figures showing the exposure for the 12-month period the heights on the shore are given as above or below M.S.L., and also in their relation to the arbitrary scale of the recorder traces.

The general form of the exposure curve is similar to that found by Doty (1946). Around M.S.L. the exposure increases or decreases rapidly and there is a gradual increase to the maximum and minimum exposures.

(d) Monthly Exposures for November, 1947-October, 1948

(1) November, 1947. (Figure 13)

M.S.L. for this month was at 10 feet 4½ inches Recorder datum (R.D.). Zero exposure was at M.S.L. minus 1 foot 7 inches, and 100 per cent exposure was at 1 foot 4 inches above M.S.L. The zero exposure on the shore was at a low level but this was not likely to be serious to littoral organisms in view of the moderate climatic conditions encountered in that month. Exposure at M.S.L. was 50 per cent.

(2) December, 1947. (Figure 14)

M.S.L. for this month was 10 feet 7 inches. The zero exposure was slightly further up the shore than for November (minus 1 foot 6 inches) and the 100 per cent exposure occurred at 1 foot 3 inches above M.S.L. In spite of these figures some very low tides were recorded towards the latter part of the month. This month must be regarded as one of great trial for littoral organisms as the average monthly rainfall is high (2·28 inches), and in this particular year 4·91 inches was recorded. The maximum air temperatures were not high but the minimum air temperatures were the highest for the year. The sea was cool. When exposed an organism had to endure warm temperatures and high rainfall and when the tide came in, cool seas. The lowest tide for the year occurred this month (7 feet 4 inches R.D.). The exposure at M.S.L. was 46 per cent.

(3) January, 1948. (Figure 15)

M.S.L. for this month was 10 feet 4½ inches R.D. Zero exposure occurred at the lowest on the shore for the twelve months under consideration (8 feet 6½ inches R.D.) At 1 foot 6 inches above M.S.L. is the 100 per cent exposure level. This month must be regarded as the month of maximum desiccation, especially at the lower tidal levels. The 'low low' tides reached their lowest monthly average height this month. The air temperature was high, relative humidity low and the sea temperatures at their maximum. The waters left by the tide would thus evaporate quickly. It is worth noting that the afternoon tide during this time of the year is the 'low low' tide which allows the maximum effect of the desiccation factor to operate at the lower tide levels. The exposure at M.S.L. was 54 per cent.

(4) February, 1948. (Figure 16)

M.S.L. for this month was 10 feet 5½ inches. The maximum and minimum exposures were found to be at 1 foot 6 inches above and below M.S.L. respectively. The maximum air temperature was recorded this month and the average monthly rainfall was at its lowest. The seas were cooler and the relative humidity higher than last month. Although the air temperatures for this month were higher I do not consider it to have such a high desiccation effect as January due to the slightly higher M.S.L., the raising of the zero exposure level and the less evaporation of water. Exposure at M.S.L. was 57 per cent.

(5) March, 1948. (Figure 17)

M.S.L. for this month was 10 feet 6 inches (R.D.). The most noticeable feature of this month was the level of the zero exposure mark at 9 inches below M.S.L. This month might be described as a very moderate month from the nature of the weather to which the organisms were exposed. Those organisms living low down in the intertidal region were not exposed very much and if they were exposed it was to relatively mild conditions. The exposure at M.S.L. was 38 per cent.

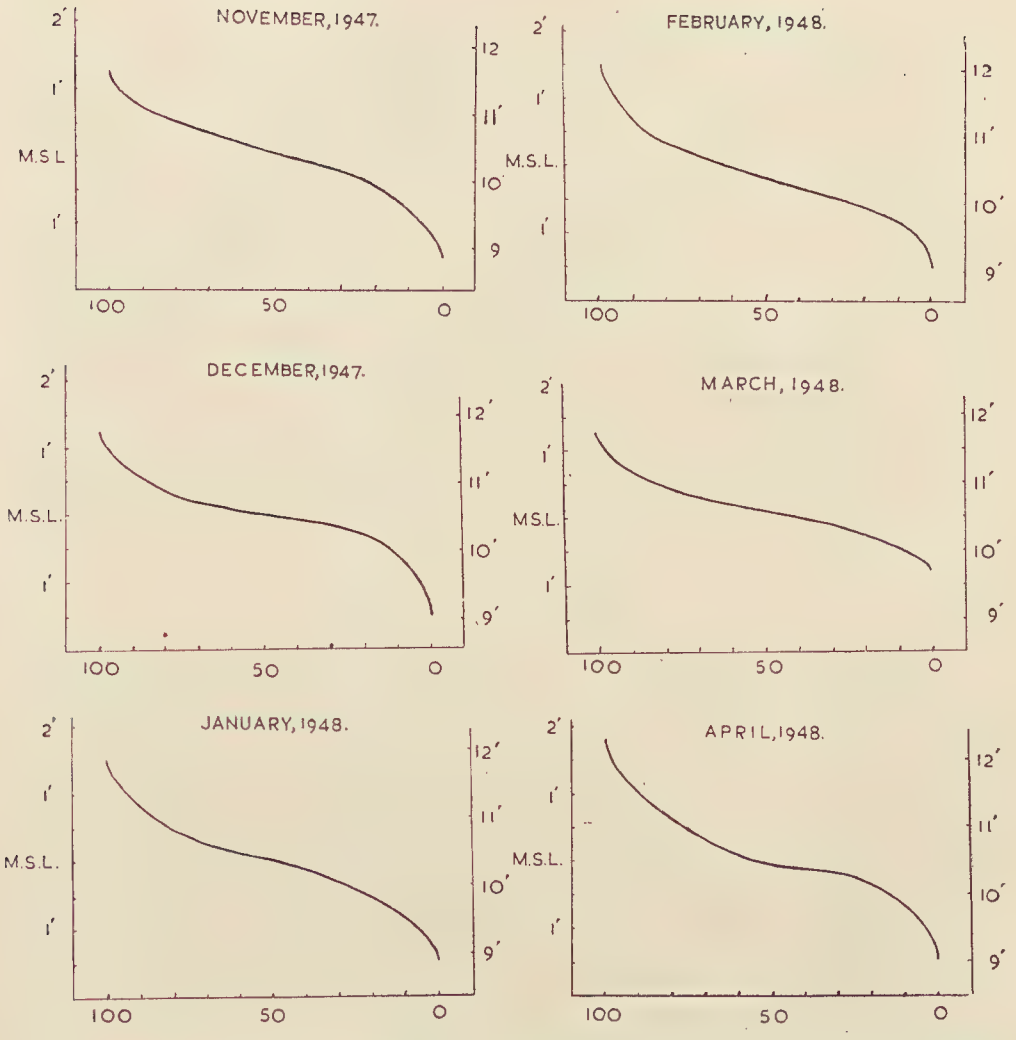

FIG. 13.—Exposure curve for November, 1947. Heights expressed in terms of above or below M.S.L. and also in relation to R.D.

FIG. 14.—Exposure curve for December, 1947. Heights expressed in terms of above or below M.S.L. and also in relation to R.D.

FIG. 15.—Exposure curve for January, 1948. Heights expressed in terms of above or below M.S.L. and also in relation to R.D.

FIG. 16.—Exposure curve for February, 1948. Heights expressed in terms of above or below M.S.L. and also in relation to R.D.

FIG. 17.—Exposure curve for March, 1948. Heights expressed in terms of above or below M.S.L. and also in relation to R.D.

FIG. 18.—Exposure curve for April, 1948. Heights expressed in terms of above or below M.S.L. and also in relation to R.D.

(6) April, 1948. (Figure 18)

M.S.L. for this month was 10 feet 5 inches (R.D.). This month saw great tidal disturbances which culminated in the equinoctial change which made the early morning tide the 'low low' tide. The operative temperature factor during this part of the year must be the minimum temperature which would occur sometime during the early hours of the day. Hedley (1915) noted that for Sydney the critical time for littoral organisms was a low spring tide on a winter night. The minimum exposure was not as high on the shore as in March. The exposure curve has a slightly different form from that of the other months of the year. This may be due to incomplete records for the month as three days are missing from the recorder trace. This month saw sharply falling sea temperatures and maximum air temperatures also fell sharply. The minimum air temperature rose slightly from that of March. The rainfall average is similar to that of March but the relative humidity had risen very sharply. This month is to be regarded as a time of stress for littoral organisms, not on account of extremes of temperature, but because of the equinoctial change from low water maximum exposure to warmth to low water exposure to cool conditions. This will not affect animals living high up the shore. This change may serve as an indication to forms dwelling in the sublittoral fringe that it is time for the off-shore migration to commence. The exposure at M.S.L. was 56 per cent.

(7) May, 1948. (Figure 19)

M.S.L. for this month was at the remarkably high level of 11 feet 1½ inches R.D. This may be correlated with the general fall in barometric pressures for that month (figure 7). While this fall in pressures may account for some of the rise in M.S.L. a combination of local factors must be taken into consideration. Zero exposure was correspondingly high up on the shore at 9 feet 2 inches R.D. This means that the extreme low water for the month must have only rarely exposed those organisms dwelling at the lower intertidal levels. Sea and air temperatures fell during the month. The average rainfall for the month is lower than for April but the actual rainfall recorded was above that for April. The relative humidity remained high. This month is not a time of stress to those organisms which enjoy submersion but for those with an optimum immersion there may be some difficulty in surviving. The exposure at M.S.L. was 50 per cent.

(8) June, 1948. (Figure 20)

M.S.L. for this month reverted to 10 feet 5¼ inches R.D. The zero exposure was 1 foot 7 inches below M.S.L. 100 per cent exposure was at 1 foot 8 inches above M.S.L. The relative humidity for the twelve months was at the maximum of 76 per cent. The average rainfall is high though the actual rainfall for the month was low, the minimum air temperature was at the second lowest for the twelve months. The sea temperature was also low. This month is one of endurance to cold for littoral organisms. As mentioned above the 'low low' tide occurs during the early hours of the morning and this must often be accompanied by frosts. We have also noted Hedley's remark that a low spring tide on a winter morning is critical for littoral organisms. The most critical time of all is when a low spring tide coincides with low temperatures and a strong wind. Under exceptional circumstances this wind can cause virtual extermination of some littoral species but if sheltered from the wind individuals of the same species

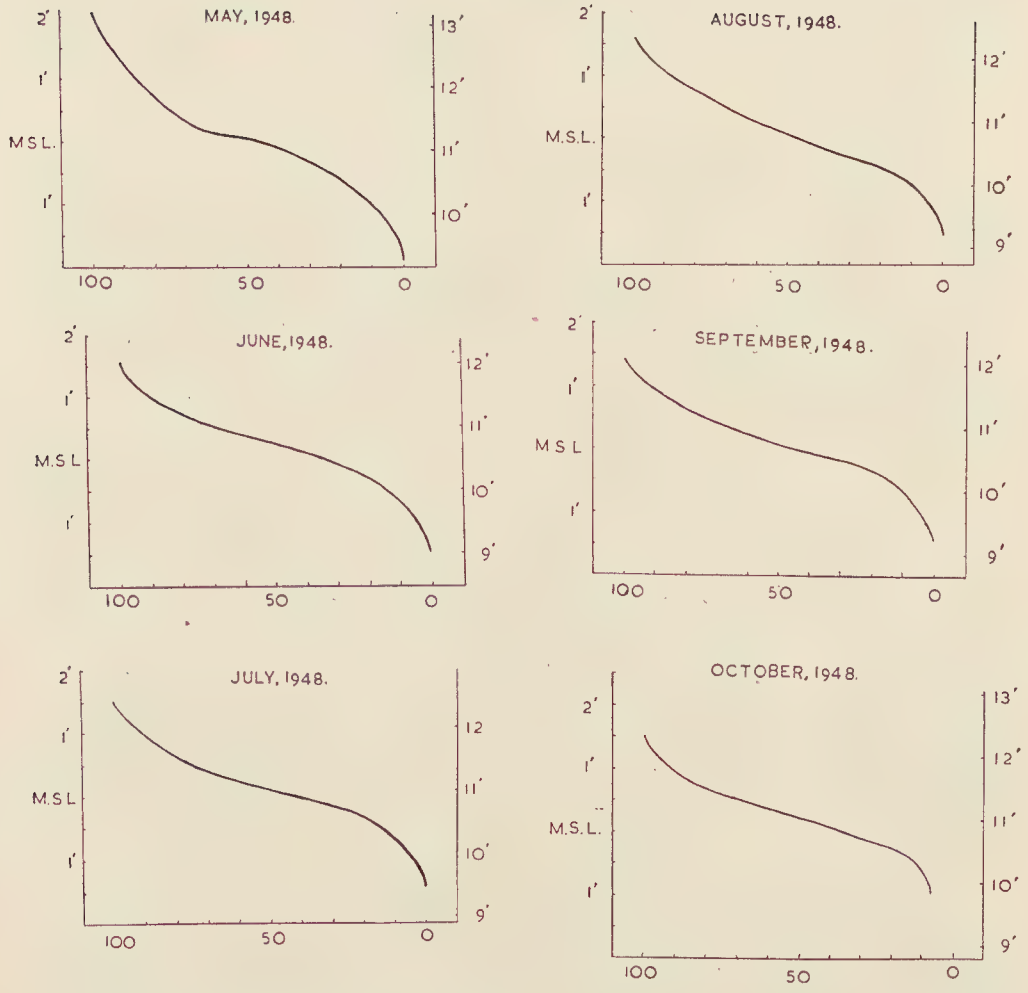

FIG. 19.—Exposure curve for May, 1948. Heights expressed in terms of above or below M.S.L. and also in relation to R.D.

FIG. 20.—Exposure curve for June, 1948. Heights expressed in terms of above or below M.S.L. and also in relation to R.D.

FIG. 21.—Exposure curve for July, 1948. Heights expressed in terms of above or below M.S.L. and also in relation to R.D.

FIG. 22.—Exposure curve for August, 1948. Heights expressed in terms of above or below M.S.L. and also in relation to R.D.

FIG. 23.—Exposure curve for September, 1948. Heights expressed in terms of above or below M.S.L. and also in relation to R.D.

FIG. 24.—Exposure curve for October, 1948. Heights expressed in terms of above or below M.S.L. and also in relation to R.D.

will survive. This was noted during the freeze-up of the British coasts in 1947 when the ice-sheet protected organisms from the wind but when the sheet was ruptured and the wind allowed to penetrate into the littoral zone great slaughter ensued. Forms dwelling at L.W.S.T. had no covering ice-sheet and were virtually exterminated (Guiler, 1949). Exposure at M.S.L. was 38 per cent.

(9) July, 1948. (Figure 21)

M.S.L. was at 10 feet 9 inches R.D. The zero exposure was at 1 foot 6 inches below M.S.L., i.e., fairly high on the shore. The 100 per cent exposure was at 1 foot 6 inches above M.S.L. Air maximum and minimum temperatures were at the lowest for the twelve months. The rainfall was low and the relative humidity was much lower than in June. The month is to be regarded as one of greatest cold although the absolute minimum air temperature was not recorded until next month. To some extent those organisms dwelling lower down on the shore were protected by the elevation of the zero exposure. The highest tide for the twelve months (13 feet 10 inches R.D.) was recorded this month. Exposure at M.S.L. was 41 per cent.

(10) August, 1948. (Figure 22)

M.S.L. for this month was 10 feet 8½ inches R.D. The maximum and minimum exposures were at 1 foot 7½ inches and 1 foot 7 inches above and below M.S.L. respectively. In spite of the absolute minimum temperature for the year being recorded on the 18th of the month there was a general warming up of temperatures. The relative humidity was still falling. Exposure at M.S.L. was 46 per cent.

(11) September, 1948. (Figure 23)

M.S.L. for this month was 10 feet 7 inches. The exposure limits were still fairly high on the shore being 1 foot 5 inches above and below M.S.L. The temperatures of air and sea showed an increase and the relative humidity fell further. There was a sharp increase in rainfall. The sea temperature rose sharply and this factor alone must make this month one of growth and recovery for littoral organisms. The exposure at M.S.L. was 43 per cent.

(12) October, 1948. (Figure 24)

M.S.L. for this month was 10 feet 9 inches R.D. Maximum and minimum exposures were at 1 foot 6 inches above and 1 foot 7 inches below M.S.L. respectively. The minimum air temperature fell for the month compared with September while the maximum air temperature rose in comparison with that month. The sea temperature and rainfall continued to rise. The latter was very high at 4·11 inches for the month. In general this month may be considered to be fairly mild, the organisms not being exposed to extremes of temperature. Exposure at M.S.L. was 38 per cent. This latter would serve to protect those animals dwelling low down on the shore. This month showed the equinoctial change over of the 'low low' tides and the remarks for April will also apply to this month.

(d) Discussion and Conclusions

It can be seen from the above that the exposure at the same point on the shore varies considerably from month to month. Comparison of two months in which the M.S.L. is the same shows considerable difference in the exposure at say, 10 feet 0 inches R.D. (November, 1947, and January, 1948, have the same M.S.L.). This variation in exposure is not therefore entirely due to the variation in M.S.L., but the composition of the tide for the month is an important factor. There is

reason to assume that the exposure will also vary considerably from year to year as Zanefeld (1937) has shown that tidal levels may alter considerably from one year to the next. As regards the effect of exposure on littoral organisms it can be seen that the level of the organism on the shore must be noted accurately in relation to tidal levels and that the exposure is governed by two variables; the M.S.L. and the composition of the monthly tides and their relation to M.S.L.

The month of December is one of great trial for littoral animals and plants due to the variable weather liable to be encountered during that month. With low tides and heavy rainfall those animals and plants which are stenohalic must have a trying time. January showed itself to be a critical month for stenothermal organisms. April and October will greatly eliminate those organisms of low individual adaptability due to the equinoctial change over of the 'low low' tide. July is the month of maximum cold and stenothermal organisms must again suffer in this month.

In conclusion we find that December, January, April, July and October are months of some trial for littoral animals in Southern Tasmania. In this the emphasis lies on December, January and July which are critical months. These conclusions may apply in a general sense throughout Southern Australia. Further, it has been shown that the M.S.L. and the exposure at a point on the shore vary from month to month.

Part V.—Shore Topography

(a) The Estuary of the River Derwent

The river is tidal to beyond New Norfolk. For much of this distance the river is composed mainly of fresh water with a layer of salt water on the bed of the river. The banks of the Derwent in the upper tidal reaches are of a fresh water facies and show little or no evidence of saltwater. For the purposes of this work it is intended that upper limit of the area surveyed shall be at Bridgewater and the lower limit is the mouth of the estuary on an imaginary line drawn between Pierson Point on the West bank of the river and Cape Direction on the East shore.

(1) The West Shore

The upper part of the stretch of shore under consideration has marshes on this bank and at low tide considerable areas of mud flats are exposed, with a mixiumum exposure at the bird sanctuary above the bridge at Bridgewater. There are numerous muddy shoals in the stretch of river immediately below the bridge.

Between Bridgewater and Cadbury's (Dogsear Point) the river is of varying width with low headlands and several large bays. There is a deep water channel with a depth of not less than 4 fathoms. The bays are mostly shallow with shoals, reefs and sunken logs. There are certain exceptions as some of the bays, e.g., Claremont, are of 3 or 4 fathoms depth. The bank of the river is low-lying and composed of marshes and muddy sand beaches with low points of mudstone.

At Cadbury's the river swings sharply East, then West before flowing South again. This diversion is caused by a ridge of mudstone where the factory is situated. The water at this point is deeper than usual being 36 feet to the bottom. Beyond Cadbury's the river is broad and of uniform depth as far downstream as the Zinc Works. Prince of Wales Bay opens by a narrow entrance into the main channel immediately North of the Zinc Works. It is an enclosed bay of a fairly uniform depth of four fathoms and has two small streams entering it. The bay suffers from pollution from the refuse dump of the Glenorchy Municipality, open drains and to a lesser extent from factory effluvia from the development area at Derwent Park.

The Zinc Works is situated on a point some 225 feet in height. The estuary at this point is narrow being less than one half of a mile in width. The Zinc Works uses electrolytic processes and there is very little effluvia or pollution of the river. The water is of sufficient depth to permit ocean going vessels to berth at the wharf at the Works. Here there are 10 fathoms of water.

From the Zinc Works to the open sea at Storm Bay the river flows due South and is of gradually increasing width to a maximum of 3½ miles at the mouth.

Immediately beyond the Zinc Works, New Town Bay extends in a Westerly direction. The maximum depth of this river is four fathoms. The North shore is of rocks with low cliffs. At the head of the bay New Town Creek enters the bay and here also is the Hobart City refuse dump. The South shore has flat reefs of decomposed igneous material which are covered by a thin film of mud supporting a large Nereid fauna. There are low cliffs at the top of the shore and they form the next promontory, Cemetery Point. The reefs do not extend beyond the entrance to New Town Bay.

The next bay, Cornelian Bay, is of coarse sand at the Cemetery Point end and is composed of sandy mud at the Railway end. There is a negligible amount of fresh water entering the bay. The shore line from Cornelian Bay to the next point, Macquarie Point, is of stones with a muddy substratum. In places the stones are replaced by a gravel bottom on a substratum of mud. There are jetties and wharves on this stretch of coast and several slipways. Hobart bridge, a floating pontoon structure, spans the river below the Newsprint Mills' wharf. The shipyards and Naval Station lie half-a-mile downstream from the bridge.

The Hobart Rivulet enters the Derwent River just upstream from the oil jetty at Macquarie Point. A few yards out from the oil jetty a large sewage outfall causes a considerable upwelling of water. At the time of writing the Marine Board of Hobart are carrying out construction work on the stretch of shore between the oil jetty and the port of Hobart. This shore line is composed of an artificial wall but this will probably undergo some alteration in view of the extension work.

The port of Hobart lies in Sullivan's Cove. Ocean Pier lies at the Northern end and Prince's Pier at the Southern end of the Cove. A true shore line is not visible anywhere on this stretch of shore as most of this area is reclaimed. At extreme low water a line of stones is exposed at the Argyle Street end of Constitution Dock. Fresh water from street drainage enters this dock.

An artificial shore line extends around Battery Point. Below this wall is a foreshore of boulders. The wall is replaced by a low cliff at the Port Huon Fruitgrowers Factory. This cliff continues for some distance being broken by several small inlets which have a very muddy substratum with a number of small stones embedded in the mud. The cliffs terminate just before the outlet of the Wellington Rivulet.

At the Wellington Rivulet a coarse sand-shingle beach with a few loose stones extends almost as far as the Sandy Bay site of the University. A new promenade of loose stones and soil is in the course of construction at this point. It is not yet possible to judge what effects this will have on the shore facies. Immediately off-shore the substratum at the University end is composed of a sandy mud with a large Nereid fauna. A small amount of fresh water enters the sea at this spot and flows down a concrete channel for the last few yards of the outfall.

A low sea wall runs alongside the Sandy Bay Road for a hundred yards and this is replaced by a series of low cliffs which terminate at Dunkley's Point, better known as Wrest Point. The substratum is of sand. Beyond the point the road runs alongside the beach for some distance with a wall 20 feet high separating

it from the sea. This wall is intertidal in the lower portions. Following on this wall there is a stretch of coast with sandy bottom and rocky cliffs varying between 5 and 20 feet in height. A long sandy beach forms most of the intertidal region and this terminates in a sandy spit at Long Point which is backed by sand dunes. Long Beach is of sand and separates Long Point from Blinking Billy Point. The latter is composed of large boulders of sedimentary and igneous material lying on a rock outcrop of dolerite. The main sewage outfall for Hobart lies off this point.

Next there is a sandy beach which runs for about one hundred yards to another small point. Above extreme high water mark there is a belt of pebbles which extends along the length of the beach. Above the pebbles are sheer cliffs of mudstone which are never less than 30 feet high.

This general type of coast, a rocky point followed by a beach, continues as far as Crayfish Point near Taroona. The upper regions of the beaches are usually of a rocky nature. The most noticeable feature of the coast is the absence of any kind of rock platform such as is common further down the coast although there are several large rocky masses on various parts of the foreshore.

At Crayfish Point the coast swings sharply through a right angle and runs in a westerly direction. The beach on this stretch of coast is composed of sand with several rocky outcrops. At the end of this sandy stretch there are high vertical cliffs which follow the general North-South trend of the shoreline. At the bottom of the cliffs are screes and small rock platforms. These high cliffs continue as far along the shore as Kingston.

At Kingston there is a long beach of some half-a-mile in length with fine sand and no rocks. A river, Brown's River, enters the estuary at approximately a quarter of the distance along the beach from the Hobart end. Between Kingston and the next bay, Blackman's Bay, there are further steep cliffs. These at first have no rock platforms but approaching Blackman's Bay platforms, all of which are of mudstone, are found. These platforms extend up to 50 yards out from the base of the cliffs and are penetrated by several wave-cut openings of which the largest is at the Blow Hole. Perameles Bay is a small indentation just to the North of the Blow Hole.

Blackman's Bay, not to be confused with the Blackman's Bay on the East Coast at the East end of the Dunalley Cut, is of sand extending for about a third-of-a-mile. The Northern headland is formed of the Southern end of the rock platforms. At the Southern end of the beach there is another rock platform with a stack called the Pinnacle at the shoreward side of it. The cliffs are high and composed of mudstone. Following on Pinnacle Point is a bay which I call Boulder Bay on account of the type of foreshore, which is about three hundred yards in length, having an outcrop of mudstone in the middle and ending in a rocky point of dolerite.

A very deep wave cut opening, which has vertical sides and terminates in a cave at the landward end, separates this point from the next bay which I have called Inaccessible Bay. The shore is of boulders with sheer steep cliffs on the landward side. The coast from this bay as far as Pierson Point is of a similar nature with steep cliffs and a stony or rocky substratum. Much of the coast is difficult of access. Many of the bays are more in the nature of indentations than true bays such as Blackman's Bay. A noticeable feature is the lack of rock platforms. This is not due to a change in rock formation. This part of the shore is characterised by a large belt of kelp at a distance of some twenty yards off-shore.

(2) The East Shore

In the upper reaches this shore is similar in form to that described above for the West side of the river. About a mile below Bridgewater the River Jordan enters the main stream. This river is of considerable width but in summer the amount of fresh water being added by it to the main stream is very small.

Below this river the East bank of the estuary is of a more uniform nature than the West. Opposite Cadbury's the bank of the river is steep but the rest of the shore is of gentle slopes with stony beaches. This type of bank continues as far as Risdon Cove, an inlet with a small stream at the head of it. Almost opposite the Zinc Works there is a vertical slope of rock known as Bedlam Walls. Between Risdon and Lindisfarne Bay there are two long narrow indentations each with a small stream at the head of it. The smaller of the indentations is Shag Bay and the larger is Geilston Bay.

Lindisfarne Bay is of a muddy substratum with boulders and rocky outcrops at high tide level. The coast after Lindisfarne is of low rocky cliffs with a sandy bottom. This continues beyond Hobart Bridge to Montagu Bay, which is similar to Lindisfarne Bay. Montagu Point, a low rocky promontory, separates Montagu Bay from Kangaroo Bay. This bay is also of a similar nature to Lindisfarne Bay but has a rubbish tip at the head of it with a small stream entering beside the tip. A low headland of mudstone with a narrow rock platform at the foot forms Kangaroo Bluff. Beyond this headland is Bellerive Beach, with low sand dunes behind the beach. It is composed of sand and is about a mile in length. A small point of rocks separates this beach from Howrah Beach, another sandy bay about half-a-mile in length with a rocky prominence at the South end.

From this latter low point the coast is of a fairly uniform character being composed of low rocky prominences with bays having a substratum of sandy mud and loose boulders with some rocky outcrops. This type of coast terminates at Droughty Point which forms the Northern side of the entrance to Ralph's Bay.

Ralph's Bay is large and of an enclosed nature. It has a Northern and Southern arm. The Northern arm extends in an Easterly direction for about half-a-mile almost reaching Frederick Henry Bay. It has been joined to this bay by a canal. A further arm runs in a Southern direction forming a very shallow bay, much of which is only covered by the tide at high water. At the head of the bay there is a salt marsh which is now practically cut off by a road and is drying out. The larger Southern arm of the bay extends for several miles being separated from Storm Bay only by a narrow neck of sand dunes. There is a small bay on the East side of the Southern arm, Mortimer or Henry William Bay. The Southern side of the entrance to Ralph's Bay is formed by Gellibrand Point, which is higher than Droughty Point and has a loose boulder foreshore.

The shore of the Northern arm is of a sandy mud, while the Southern arm ranges from almost pure sand and with a shingle admixture to muddy sand, and at some places low rocky cliffs are to be found. In both arms there are large shell and shell fragment beds to be encountered at high water level.

The estuarine side of Gellibrand Point has a shingle beach followed by a few rocky outcrops and then Mary Ann Bay which has a foreshore of sand. A rocky coastline extends from this bay to Opossum Bay. This latter is of sand with a few low dunes and is three-quarters-of-a-mile in length. A low rocky headland separates it from another sandy beach, forming the shore of Half Moon Bay, which is very similar to Opossum Bay both as regards length and nature. A rocky headland with a narrow rock platform extends from the South end of Half Moon Bay. This is followed by several small beaches separated by mudstone areas. This type of shore terminates in Cape Direction which is also of mudstone.

The most striking feature of the topography of the estuary is the difference between the two sides. The East is of a more sheltered nature than the West. This is seen from the larger amount of mud in the shore deposits of the East bank. The Western side is of the more exposed nature as is seen from the absence of mud in the lower regions of the river, and the presence of cliffs and rock platforms. The rock platforms are characteristic of mudstone and are worn along the bedding planes of that rock and so dip at a varying angle, rarely more than twenty degrees to the West.

The difference between the shores can be attributed to the effect of a Southerly or South-Easterly sea. There is no island or any form of breakwater in the entrance to the estuary between the Iron Pot (off Cape Direction) and the North end of Bruni Island. The full force of the waves of a Southerly or South-Easterly sea is thus expended on a stretch of shore from just North of Kingston to somewhere South of Inaccessible Bay. A lesser force is felt for considerable distances on either side of this stretch of coast. This can easily be seen on a calm day with a slight Southerly swell, when the surf will be breaking on the rocks at Blackman's Bay, the depth of the waves being as much as four feet from crest to trough. Under the same conditions the East side of the estuary would be calm with only small waves. This difference is further accentuated by the very common Southerly sea breeze which springs up somewhere about mid-day in summer. Short steep seas are whipped up by the breeze and these beat on the West shore while the East shore enjoys calm.

The East shore is not affected similarly by a South-Westerly swell or gale as Bruni Island and Cape Direction between them form a bar to any heavy seas breaking on the East shore.

Part VI.—The Ecology of the Blackman's Bay Area

(a) Introduction

The area under consideration extends from Kingston Beach at the North to Pierson's Point at the South. The most intensely studied area is at Blackman's Bay. Blackman's Bay lies on the West side of the estuary of the River Derwent near the entrance to the river from Storm Bay and D'Entrecasteaux Channel.

Blackman's Bay was chosen as the first area to be studied as it is convenient to Hobart and can be visited frequently throughout the year. It is sufficiently far down the estuary to be free from fresh water influences. It does not suffer pollution by sewage or factory effluvia. Blackman's Bay was the operational base for short excursions along the coast in either direction.

The coast may be described as semi-exposed. Greatest wave action is experienced in the Pierson's Point to Lucas Point area. This is of moderate severity during a South or South-East swell or gale.

The zonation exhibited in this area is studied in some detail and some attention has been given to the colonization of rock surfaces.

It is not intended to give full lists of the flora and fauna of each of the belts examined. In the case of the upper regions of the shore the lists will be full but the lower regions will only have index and obvious species mentioned. Lists of the marine fauna of Tasmania are in preparation.

(b) Terminology

The terms used in the classification of the intertidal region vary according to the views of every author. Kjellman (1877) described the Littoral region as being from E.H.W.S.T. to E.L.W.S.T., the sublittoral from E.L.W.S.T. to 20 fathoms and the Elittoral as being below 20 fathoms. Sernander (1917) considered the region above the littoral to be the Epilittoral. Bright (1938*a* and 1938*b*) recognized the Supralittoral, Tidal and Sublittoral. Zanefeld (1937) combined the Epilittoral of Sernander with the classification of Kjellman but with many more subdivisions of the Littoral. Stephenson, Stephenson and duToit (1937) recognised three zones based on the dominant forms found there namely an upper Littorina zone, a median Balanoid and a lower Patella cochlear zone. Below the latter was the Sublittoral fringe which belongs to the Sublittoral area.

In Australia, Hedley (1915) found Upper, Median and Lower zones at Maroubra and Johnston (1917) found four or five zones at Caloundra. Pope (1943) and Dakin, Bennett and Pope (1948) all followed the South African workers. Edmonds (1948) recognised similar zones but based the limits of these zones on the work of Cranwell and Moore (1938) and Oliver (1933).

While it is necessary to consider the sub-zones recognised on the shore in view of local conditions, it has to be borne in mind that there exists an overall zonation which is common to most parts of the world. This has been pointed out in a most timely paper by Stephenson and Stephenson (1949). The basic zonation throughout the world is described. The terminology adopted by these authors is that which will be followed in this, and all subsequent parts, of the present work. The Supralittoral is that zone above the upper limit of Littorinids. The Supralittoral fringe extends from the upper limit of Littorinids to the upper limit of the barnacles. The Midlittoral is the barnacle zone extending down as far as the upper limit of the Laminarians. The Infralittoral fringe is from the upper limit of the Laminarians to E.L.W.S.T., and the Infralittoral zone is below the extreme limit of tides.

The littoral region extends from E.H.W.S.T. to E.L.W.S.T. but authors do not favour the retention of the term littoral due to too much ambiguity as to its actual meaning.

The level of E.L.W.S.T. in Tasmania is considered to be the level of extreme low water spring tides plus the extreme effects produced by wind and barometric pressure. This is the level shown on the tidal recorder and it is this level with which we are concerned.

(c) The Physical Environment

This has already been described in some detail in Parts III and IV of this work. The details noted in the earlier parts apply at Blackman's Bay without very much modification from those described for Hobart. There may be more insolation experienced due to the effect of the summer sea breezes on Mount Wellington. As noted previously cloud forms on Mount Wellington in summer when the afternoon sea breeze blows up the river. This shades the South part of Hobart but Blackman's Bay and further South are not in the area covered by the clouds.

(d) Topography

Blackman's Bay lies on the West side of the Derwent estuary. The general relationships of the bay to the shore as a whole have been noted in Part III of this work.

At both the North and South ends of the bay there are low headlands of mudstone. Rock platforms extend out for some distance from the bases of the cliffs. The bay is composed of a sandy beach about a third of a mile in extent. A very small stream enters the sea about half-way along the beach. The influence of the water brought down by this stream is negligible.

The rock platform at both the North and South ends of the beach are formed by erosion along the bedding planes of the mudstone. This rock dips to the West at varying small angles. The platforms at the South of the bay are not as extensive as those at the North end.

To the North of Blackman's Bay the coast is composed of cliffs with rock platforms. This type of coast extends nearly as far as Kingston where dolerite appears. The igneous rock has no rock platform. Perameles Bay is a small indentation beyond the Blow Hole at Blackman's Bay. It is reached by a small path from the cliff top.

The next point beyond Blackman's Bay is of igneous material. This has given rise to steep cliffs without rock platforms. Beyond this there are steep cliffs of mudstone or tillite, but without rock platform. Where beaches are found they are composed of boulders or gravel. This type of coast continues as far as Pierson's Point. The bay to the South of Blackman's Bay I have called Boulder Bay. Lucas Point lies about half-way between Blackman's Bay and Pierson's Point.

(e) Wave Action

At no time could the wave action on the shore be considered as intense. The most severe wave action is experienced when a South or South-East swell is running. This swell comes in between the Iron Pot and the North end of Bruni Island and crashes on the shore, especially severely in the Pierson's Point area. The waves are not of full oceanic strength but are modified by the shallow waters of Storm Bay and by the narrow entrance to the river.

Very choppy seas are experienced off Pierson's Point when the wind coming up the D'Entrecasteaux Channel crosses the 'run' of the sea at the North end of Bruni Island.

The quantitative measurement of the intensity of wave action is impossible to determine. The reasons for this lie in the number of unknown physical factors concerned with the effect of winds of different strengths on varying lengths of water. The necessities of war produced some researches into this problem. The studies were based on the analysis of wave curves but quantitative measures of wave forces are not given ('Discovery', 1949). In the absence of any quantitative data some comparative method of describing the intensity of wave action is all that can be undertaken.

Fischer-Piette (1932) recognised four degrees of exposure to wave action. These are 'très battu, peu battu mais encore dépourvu de Fucacées, abrité et couvert de Fucacées et très abrité'. Moore (1935) defines a factor for exposure to wave action as the number of days per hundred days in which any wind blows into the exposed aperture of the locality in question, the opening being the seawards aperture measured at a distance of half a mile.

The degrees of exposure as described by Fischer-Piette cannot be applied to Tasmania where there is a general poverty of Fucoids irrespective of the wave action encountered. Moore (1935) points out that the important factors of the effect of a shallow bottom near the shore, the distance the wind has blown over the sea are not considered in the definition as given above. Other factors not considered are the size of wave produced when the strength of wind and/or length of water traversed by the wind are not sufficient to produce the maximum wave force.

The formula proposed below does not answer the precise quantitative measurement of wave action but it is hoped that it will be of use in the comparative study of wave forces in different parts of the world. It can also be applied to giving an indication of the relative strengths of wave action on a restricted part of a coast or in a small area.

In the formula of Moore (1935) the wave action considered is the average. The average amount of wave action is important in maintaining the spray for intertidal organisms but it is the extremes of action that will kill or injure intertidal organisms. Heavy gales or protracted calms will both have a deleterious effect on the flora and fauna. For this reason averages have been kept out of the proposed formula as much as possible. Similarly meteorological data have been kept to the minimum, as figures of this nature may not be readily available in many places that are being studied.

The formula proposed is based on sea depth and character, M, wind force encountered (either recorded at any time or observed at time of visiting), W, the distance covered by the wind over water, D, and the topography, T.

Three types of sea are recognised—oceanic, *o*, continental shelf or other moderate depth, *c*, and shallow water less than 10 fathoms in depth *s*. Each of these types usually has its own characteristic wave types, the long oceanic swell of great power, the sharp seas of a continental shelf and the comparatively weak seas of shallow water. The *s* factor is included to provide for such places as lagoons, land locked bays and shallow estuaries. Coral lagoons which are usually of 25 to 30 fathoms depth would also be included under the *s* factor.

The wind factor is expressed in terms of the speed of wind observed in terms of the Beaufort Scale. This is the only quantitative force used but it is impossible to avoid doing so. If, in a general work, it is not desired to give an actual observed figure for wind strength, a comparative force can be given which will show the approximate wind strengths liable to be encountered in a yearly period. To ensure that this is not to be taken for a wind variation over a short period the Beaufort Scale readings should be placed in brackets, e.g. (2-8).

The distance covered by the wind over water is defined fully below.

The topographic factor is the most difficult to define. There are two easily recognised types of coast, the open coast and the sheltered coast. The former comprises such places as rocky headlands while the latter includes bays, estuaries, lochs, &c. Within each of these two major groups there can be recognised three further topographical types of coast. These are the fully exposed rock face and the sand-surf beach, semi-protected localities and protected places such as rock clefts. For the purposes of this work the fully exposed rock face and the sand-surf beach are defined as having no protection whatsoever. A semi-protected position is one which is protected from full wave action, e.g., a surf beach with an off-shore reef, a headland-protected bay on an open coast, &c. A protected place is one in which there is little wave action, e.g., a shore facing rock face.

The factors are thus—

M (marine) *o*, oceanic.
c, continental shelf.
s, shallow waters of less than 10 fathoms.

W (wind) The force of wind given in Beaufort Scale. This is given as an absolute figure for the time of observation or as a range encountered over 1 year (in brackets).

D (distance) 0, less than 100 yards.
1, 100 yards to 1 mile.
2, 1 mile to 20 miles.
3, 20 miles to 100 miles.
4, greater than 100 miles.

T (topographic) *a*, exposed coast; 3, fully exposed surfaces.
2, semi-exposed surfaces.
1, fully protected surfaces.
b, sheltered coast; 3, exposed surfaces.
2, semi-exposed surfaces.
1, fully protected surfaces.

The factors *a*, 1, 2, 3 and *b*, 1, 2, 3, being factors of degree of wave action have been given in the above order for convenience in working and to avoid a division factor.

A few hypothetical examples will illustrate the operation of this formula.

Example 1.—An open rocky coast on a volcanic island in mid-ocean in a gale force wind will suffer wave action equivalent to *o* 8 4, *a* 3. These factors should never be multiplied out.

Example 2.—A shore on the leeward side of the same island would have a wave action equivalent to *o* 0 0, *b* 1. In this case the shore, being completely protected by an off-shore wind would be suffering virtually no wave action which justifies it being placed in a *b* 1 category.

Example 3.—A semi-protected place in a bay of 5 fathoms depth on a sheltered coast with light airs would have an equivalent of *s* 1 0, *b* 1.

Flexibility has to be allowed in the choice of the category of the coast, as indicated in Example 2. In this example an off-shore rock would have a very different equivalent.

While there exist many disadvantages to this formula it does give some factor which is of comparative value. It may be cumbersome but practice in use soon overcomes difficulty of this nature. It has been used in several places in Tasmania and has been found to function satisfactorily. With practice one can read off the actual position and relation of an organism to its immediate environment.

The personal element will figure in all estimations as to whether an area is protected or exposed. The author has in mind for a protected place some area or spot where the wave action is never more intense than that produced by 6 inch waves. In a comparative work it is suggested that the formula should include the maximum exposure conditions liable to be encountered in the area being studied.

(f) Zonation

Fischer (1940) recognised two major zones on the shore at Hobart. The upper of these was populated by *Melaraphe unifasciata* (Gray) and the lower had *Galeolaria caespitosa* Lam. as the dominant form. He further states that these

zones are certainly comparable to those defined for Sydney by Hedley (1915). He was not able to describe the zone separating the *Galeolaria* zone from the *Laminarias*, in this case *Macrocystis pyrifera* (Turn.).

The coast falls into the Supralittoral zone, the Supralittoral fringe, the Midlittoral zone, the Infralittoral fringe and the Infralittoral zone as defined by Stephenson and Stephenson (1949).

Methods

The rocky parts of the shore were divided into a series of transects, each of which was studied in detail. The transects were taken at varying distances from each other along the shore. Only the more interesting of these are described. In many instances the transects were too close together and they merely served as checks on previous sections. The method broadly followed that described by King and Russell (1909). The relation of the zoning to the tidal levels was studied. Population counts were taken at various levels on the shore. The method of doing this was by the use of four rulers placed in the form of a square. By this method a variable area could be studied without the necessity of constructing wooden squares of various sizes. Certain difficulties were experienced on vertical faces but the use of elastic bands to hold the rulers together was found satisfactory. Attempts were made to dredge the Infralittoral zone but these were not successful. Due to the steep gradient into deep water at the edge of the platform it is doubtful if the results, had they been obtained, would have been valid.

Transect 1. (Plate 2)

Station	On rock platform at the seaward edge of Pinnacle Point at the South end of Blackman's Bay.
Dates	20th June, 1948, and various dates subsequent to this.
Type	Semi-exposed rocky coast.
Maximum wave exposure	*c* (1-8) 2, *b* 3.
Description	Transect runs from the North end of the base of the Pinnacle straight out across the platform towards the East side of the estuary (Plate 2). The platform is not wholly covered by the sea at H.H.W. (For tidal terms see Part IV of this work.) If there is a heavy swell surf crashes over most of the platform at nearly all phases of the tide. The line of transect is intersected by three channels which are to be regarded as sublittoral fringe in affinities.
Geology	The platform is worn along the bedding planes of the mudstone which dips at varying small angles to the West.
Tidal data	From the Hobart Recorder.
Physical environment	As in Parts III and IV and subsection *c* above, page 168.
Zonation	The basic zonation of the transect is as follows:— *Melaraphe unifasciata* (Gray), *Bembicium nanum* (Lam.) barnacle sps., *Galeolaria caespitosa* (Lam.). 'Patelloid' zone, *Mytilus planulatus* (Lam.) and *Laurencia botryoides* Gaillathoid.

The correlation of these belts with tidal levels is shown in Table V.

TABLE V

The basic zonation, Transect 1, Blackman's Bay area, and its relation to the major intertidal zones and tidal levels. Tidal levels are in terms of Recorder Datum.

Melaraphe unifasciata (Gray)	Supralittoral Fringe	Above 11 feet 7 inches.
Bembicium nanum (Lam.)	Midlittoral Zone	This zone is obscured in lower levels.
Barnacle species	Midlittoral Zone	10 feet 5 inches to 11 feet 7 inches.
Galeolaria caespitosa (Lam.)	Midlittoral Zone	9 feet 10 inches to 10 feet 5 inches.
Patelloid	Midlittoral Zone	9 feet 1 inch to 9 feet 10 inches.
Mytilus planulatus (Lam.)	Midlittoral Zone	7 feet 11 inches to 8 feet 7 inches.
Laurencia botryoides (Gaill.)	Infralittoral Fringe	Below 7 feet 11 inches.

Detailed Description of Transect

In the Transect (Fig. 25) *Bembicium nanum* does not occur at the edge of the platform. The reason for this is possibly that there is greater wave action at the edge of the platform and this species does not favour such action. The species is found at the upper end of the platform where wave action is much less severe. The extreme seaward edge of the platform is approximately two feet above the level of the rest of the platform. This portion of the transect is not covered by the tide but surf breaks over it during heavy weather. The effect of this wave action is seen in the raised levels at which the forms living there are found. The *Melaraphe unifasciata* living on the top of this ridge is not a pure population being mixed with some *Enteromorpha* and a few barnacles. The ridge is just high enough to permit the existence of the Gasteropod.

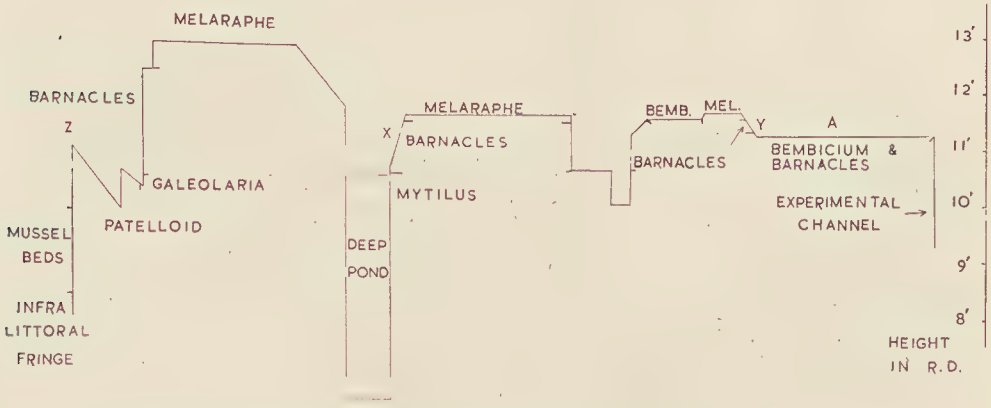

FIG. 25.—Transect 1, Pinnacle Point, Blackman's Bay. Only the major features of the zonation are shown. Horizontal scale, 1" = 3'; Vertical scale, 1" = 12'.

(1) The Supralittoral Zone

In the transect under consideration the Supralittoral zone is composed of bare rock with no lichens. One or two small stunted plants of *Salicornia* sp. are found around the base of the Pinnacle while on the cliff face are *Mesembryanthemum acquilaterale* Han., *Tetragona inflexicorna* Hook. and *Casuarina distyla* Vent. Numerous small terrestrial animals inhabit the cliff face such as lizards, rabbits and bandicoots.

(2) The Supralittoral Fringe

The sole mollusc inhabitating this belt is *Melaraphe unifasciata* (Gray). This species shows a very great salinity toleration having been collected in pools from which all water had evaporated leaving salt crystals. It has also been collected in rain water pools. The species seems to be able to remain alive for considerable periods without immersion in water.

Experiment 1.—Determination of the period for which *Melaraphe unifasciata* can remain alive without water.

Individuals of this species have been kept in glass jars without water for various periods of time. No attempt was made to desiccate the air in the jars as it was desired to obtain the period the animals could live under natural conditions. The air used was that in the laboratory and it must be regarded as drier than that encountered in nature, which is often spray laden. Controls were kept living in an aquarium tank half filled with sea water which was being aerated. A few individuals were removed from the experimental jars and control aquaria after varying periods of time. On placing these individuals in sea water the foot was always extended, usually almost immediately. Some individuals took up to five minutes to extend the foot. This greater time did not bear any relation to the length of time the molluscs were without water. It is probably an individual characteristic and stresses the importance of using at least half a dozen specimens at each examination. After a period of 70 days without water, specimens placed in sea water all took nearly 5 minutes to extend the foot. After 74 days without water some individuals extended the foot only after 10 hours. Others were dead. It is therefore concluded that a period of over 70 days without water is likely to lead to individual deaths and that specific death will ensue after a period of more than 74 days. This is a much longer period without water than would ever be encountered under natural conditions.

From the combination of observations in nature and the above experiments it can be concluded that *Melaraphe unifasciata* is not mortally affected by short term extremes of salinity and it can resist any period without water which it is likely to encounter naturally. Broekhuysen (1940) has shown that there exists a close correlation between the salinity at which a species ceases to crawl and the vertical distribution of that species. In *Melaraphe unifasciata* crawling was greatly inhibited at a salinity of 16·0 grs./mille. and ceased at approximately 14·0 grs./mille. These figures are not as low as those given for *Littorina knysnaensis* Philippi by Broekhuysen (1940).

In the particular transect under consideration there are no other macroscopic animals occurring in this belt. A lichen, which I have been unable to identify, is found very sparsely in the belt. It is the only plant species found.

Exposure in the Supralittoral fringe varies from 100 per cent to 98 per cent in January (the month of maximum exposure) to 74 per cent to 90 per cent in May (the month of minimum exposure). These figures are based on the levels at the landward end of the transect and not the elevated levels at the end of the platform. The percentage exposure is obtained from the monthly exposure curves in Part IV of this work.

(3) The Midlittoral Zone

Within this zone there are five belts. Reading from the top of the zone down they are the belts of *Bembicium nanum*, a barnacle belt, *Galeolaria* belt, a *Patelloid* belt and a *Mytilus planulatus* belt. Distributed throughout the belt is the lichen noted above. It reaches maximum development in the barnacle belt.

Bembicium nanum is dominant in the upper region of the Midlittoral. It follows immediately below *Melaraphe unifasciata*. At the junction of these two belts there is a mixing of the two species forming a narrow mixed band of some 3 inches vertical width. This mixing is a feature of the upper and lower limits of most of the belts seen.

The belt may be submerged at 'high high' water with the minimum exposure in May (51 per cent) and the maximum exposure in January (98 per cent).

A parallel experiment to that described above (Exp. 1) was carried out on individuals of *Bembicium nanum*. The results of Experiment 2 showed that specimens of *Bembicium nanum* died at various times between 51 and 59 days after their last immersion in water.

Individuals of *Bembicium nanum* have been collected well down in the barnacle belt which follows below their normal zone.

The barnacles are chiefly of three species, *Elminius modestus* Darwin, *Chamaesipho columna* (Spengler) and *Chthamalus* sp. The barnacles are found on the surface and on the seaward edge of the platform. The species on the latter place are mostly *Chamaesipho columna* and *Chthamalus* sp., but those on the surface of the platform are of the three species noted above. The *Chthamalus* sp. extends further up the shore than does *Elminius modestus* while *Chamaesipho columna* is the most restricted in distribution, being confined to the lower parts of the zone. The upper limit of *Elminius modestus* is about the lichen patches described below.

The barnacles prefer places which are sheltered from strong insolation and, at the same time, exposed to some wave action. The barnacles are largest and most numerous on the seaward face of the platform. Here they experience early morning sun and are exposed to the full amount of wave action. Where there are similar conditions of sun exposure but less wave action the barnacles are small.

The barnacles on the exposed face reach their maximum development at a height of 11 feet 2 inches, Recorder Datum (R.D.). Above or below this level they decrease in size (Table VI and Fig. 26). The theoretical exposure at this level varies from 90 per cent in January to 62 per cent in May, but is of very little value as spray from waves must alter the exposure considerably. While spray is able to reduce the amount of desiccation that a species has to suffer, it does not offer the same opportunity for feeding as does constant immersion. In the case of plankton feeders such as barnacles the upper limit of their vertical distribution will be controlled by the factors of desiccation and exposure in the most general sense and also by the time available for the obtaining of food. In the particular case under consideration the increase in exposure during the summer will be to some extent off-set by the shelter obtained from the sun.

TABLE VI

Relation between the size of barnacle and the level on the shore at which it is found.

Size of barnacle in mms.	Level on shore in R.D.	Size of barnacle in mms.	Height on shore in R.D.
5.0	13′ 2″	14.1	11′ 8″
5.75	12′ 11″	15.5	11′ 5″
6.90	12′ 8″	16.9	11′ 2″
7.75	12′ 5″	13.0	10′ 11″
10.0	12′ 2″	10.9	10′ 8″
12.0	11′ 11″	7.75	10′ 5″

Individual barnacles living at the same or even lower levels than those on the face of the platform are much smaller in size than the exposed barnacles. Those which are subjected to isolation on the horizontal rock surfaces are rarely more than 5·0 mm. in height.

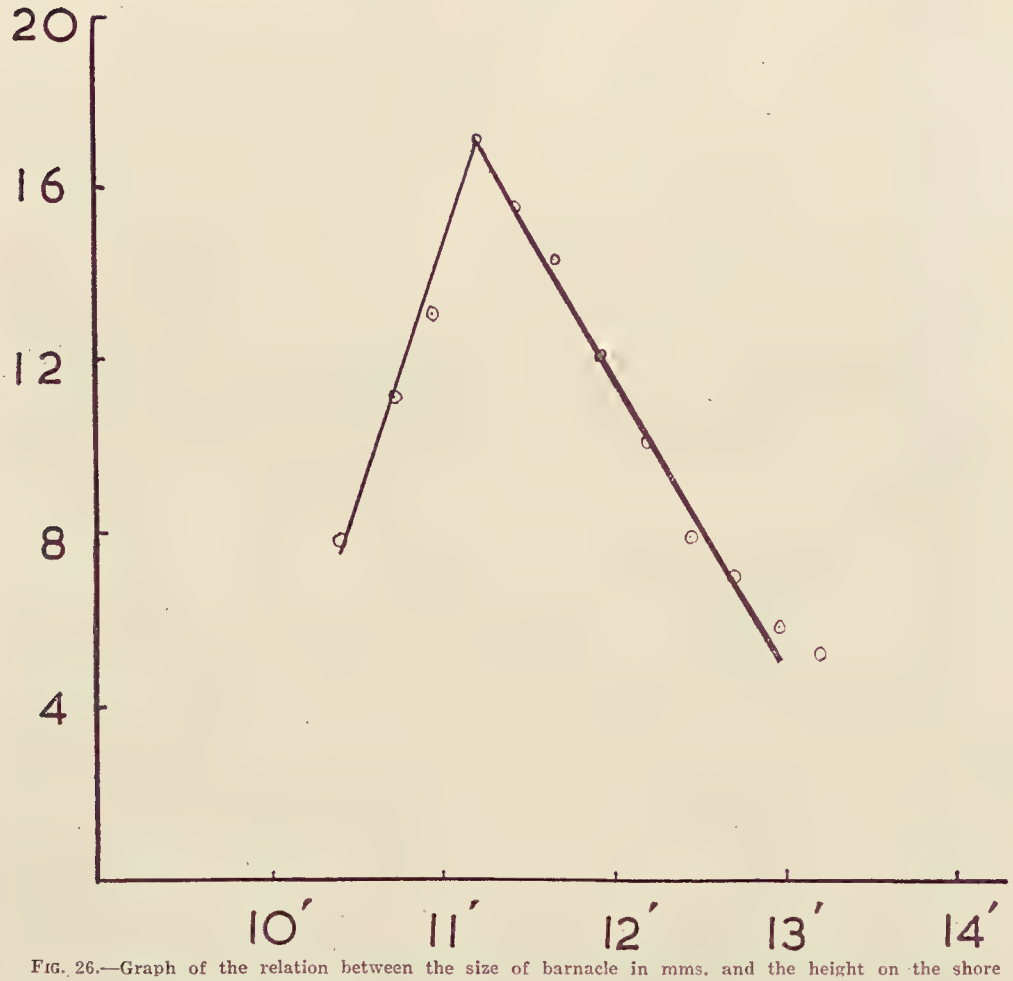

Fig. 26.—Graph of the relation between the size of barnacle in mms. and the height on the shore at which it is found.

The lateral plates of the barnacles on the seaward face of the platform project above the terga. There is a correlation between the amount of this projection and the height of the barnacle on the shore (Table VII and Fig. 27). There is also some correlation between the size of the barnacle and the amount of the above projection but this is obscured by the fact that many of the lateral plates have been broken. In all the above cases the figures are based on an average of a count of 10 individuals in a restricted area. It is not possible to count more individuals as a change in the conformation of the rock gives a change in the form of the barnacle. A barnacle growing on a cleft in the rocks is larger than one growing on a level surface. Specimens growing on a vertical surface may differ from either of the above.

TABLE VII

The height of the lateral plates of barnacles above the terga in relation to the level on the shore at which the barnacles are found.

Height on Shore in R.D.	Overlap of plates in mms.	Height on Shore in R.D.	Overlap of plates in mms.
13′ 2″	1.8	11′ 8″	3.2
12′ 11″	2.0	11′ 5″	4.0
12′ 8″	2.0	11′ 2″	5.0
12′ 5″	1.8	10′ 11″	5.5
12′ 2″	2.2	10′ 8″	6.75
11′ 11″	2.5	10′ 5″	7.75

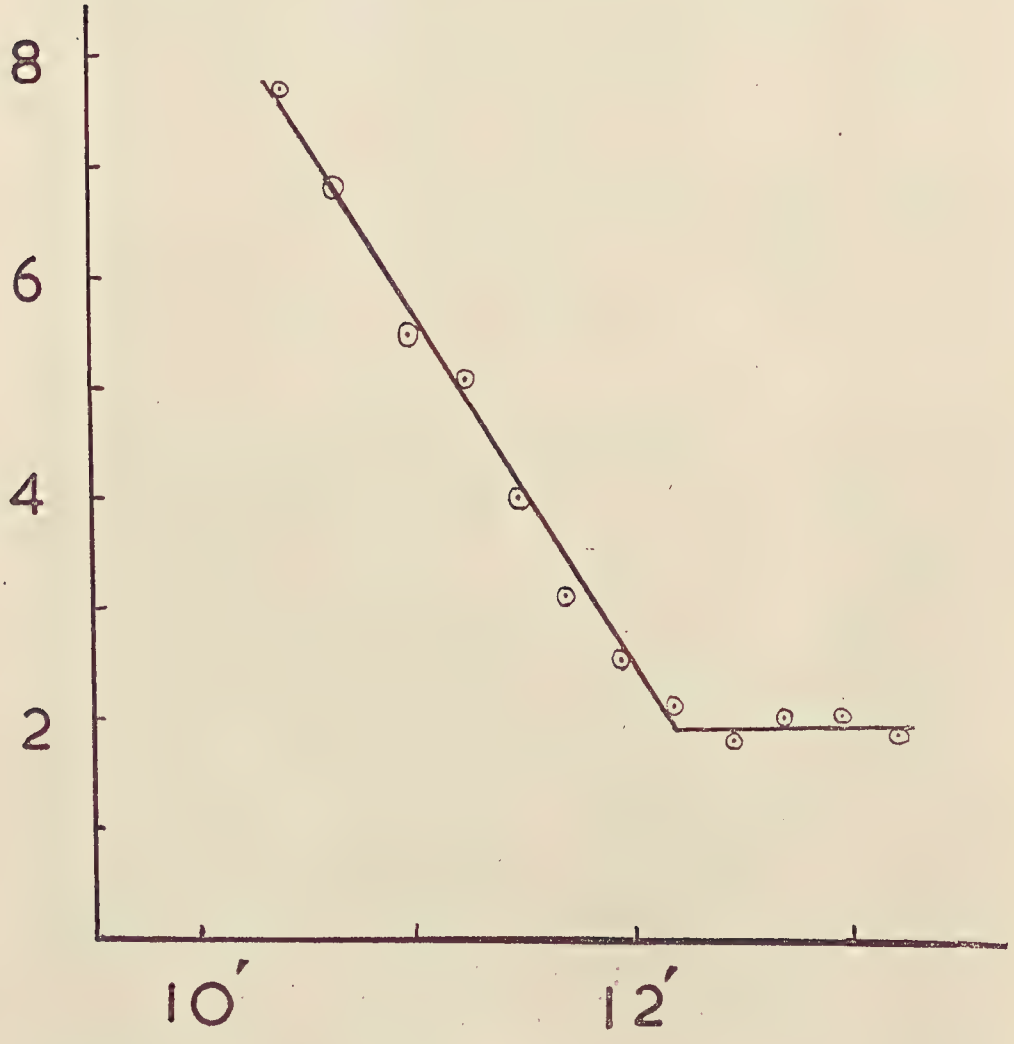

FIG. 27.—Relation between the height at which a barnacle is found on the shore and the distance the lateral plates project above the terga (in mms.).

Barnacles are most numerous at the seaward end of the platform, an average of three 'picked random' counts being 210 individuals per 10 cm. square. A 'picked random' count may be defined as a count taken at random in an area picked out as not showing any specialized or abnormal features. On the top of the platform at the seaward edge, where the spray must not be very much less than that experienced by the vertical face, the number of individuals per 10 cm. square is only 45.

On the upper surface of the platform, at A on the transect (Fig. 25), in a mixed belt of *Bembicium nanum* and *Chthamalus* sp., there occurs an irregular patch of lichen. This patch is approximately 4 feet in length and 5 feet in width, The rock between the lichen is densely populated by *Elminius modestus*, *Chthamalus* sp., *Bembicium nanum*, young *Melaraphe unifasciata* and the Lamellibranch *Lasaea australis* (Lam.). The density of population of the various species both in the lichen patch and on the surrounding rock is shown in Table VIII.

TABLE VIII

The density of population of certain animal species on a lichen patch compared with those on nearby bare rock.

Species	Numbers on lichen	Numbers on bare rock
Elminius modestus Darwin and *Chthamalus* sp.	100 to 146 per 10 cm. sq.	29 per 10 cm. sq.
Bembicium nanum (Lam.)	12 per 30 cm. sq.	1 to 3 per 30 cm. sq.
Melaraphe unifasciata (Gray)	90 per 10 cm. sq.	Nil
Lasaea australis (Lam.)	40 per 10 cm. sq.	Nil

The lichen only formed dense patches at two places on the whole platform. The reasons for this limited distribution are somewhat obscure. The substratum chosen by the lichen for dense colonization is pitted by numerous hollows up to 3 inches in diameter. Similar areas of rock at the same level are to be found on the platform but the dense lichen only occurs at one other place with a smoother substratum.

As the barnacles *Elminius modestus* and *Chthamalus* sp. are widespread on the platform at the level of the lichen patches, the increase of numbers per unit area in these patches must be regarded as correlated with the presence of the densely packed lichen. Where the lichen occurs as very small patches there is no increase in the numbers of barnacles per unit area. The retention of moisture by the lichens is the probable reason for the increase in the population of the barnacles and other species. The lichen would further give assistance to the barnacles at the most critical period of their life history, namely at the time of settling of the cyprid larvae. The lichen would act as a sieve which would arrest the larvae prior to their settling. It would also assist the larvae to remain in the one area when, as has been shown by Visscher (1928), they are testing the substratum before fixation. Shelter from insolation would give a greater percentage successful spatfall. Pyefinch (1948) has shown that in the case of *Balanus balanoides* the settlement is confined primarily to cracks, crevices and other irregularities of the surface. The lichen will virtually increase the number of crevices on the platform surface.

The lichen also offers protection for the Gastropods and *Lasaea australis*. This Lamellibranch does not occur on the surrounding platform and its presence here in such large numbers gives some indication of the intertidal population, that might be encountered, if there were some algae capable of colonizing the region.

The exposure in the belt is 18 per cent to 100 per cent in May and 48 per cent to 100 per cent in January. It must be emphasised that these figures are based on the barnacles situated on the vertical face at the end of the platform. More valid figures may be obtained by considering the barnacles further back on the shelf towards the Pinnacle. The exposure for barnacles at X (Fig. 25), a sun- and wave-sheltered channel, are 18 per cent to 58 per cent in May and 48 per cent to 90 per cent in January. At Y, a sun exposed and wave sheltered place, the figures for May are 40 per cent to 58 per cent and in January 82 per cent to 90 per cent. These figures, being based on average tidal levels for a month, do not take into account the extremely high tides which may be encountered, nor do they allow for the above average normal high tide.

The barnacle *Ibla quadrivalvis* Cuvier is found in clefts in this belt. It is not common and occurs within the range of *Elminius modestus*.

The serpulid worm *Galeolaria caespitosa* (Lam.) forms a belt of calcareous tubes below the barnacles (Plate 1). The upper limit of the *Galeolaria* belt is mixed with barnacles. The lower limit extends down into the *Mytilus planulatus* belt.

The belt is not extensively colonized by other forms. This is due partly to the intensity of serpulid colonization and to other reasons which will be discussed below. The worm tubes do not produce masses up to 6 inches deep such as have been found in other places in Tasmania, but form a thin continuous incrustation not more than two tubes thick. On a vertical face the width of the pure belt rarely exceeds 4 inches.

Exposure in the *Galeolaria* belt is from 15 per cent to 22 per cent in May and 60 per cent to 73 per cent in January.

The worm tubes extend into the next belt, that of several *Patella*-like organisms, namely *Patelloida alticostata* Angas, *Siphonaria diemenensis* Quoy and Gaim. and *Cellana variegata* (Blainville).

The zone is well defined. The upper levels are invaded by *Galeolaria* and a few *Elminius modestus* and *Chthamus* sp. The lower levels are invaded by a few small *Catophragmus polymerus* Darwin. In the lower part of this belt there is to be found a sub-belt of *Brachyodontes rostratus* Dunker. The belt is not continuous but occurs regularly at this level on different parts of the coast and is of sufficient importance to warrant inclusion as a sub-belt. These mussels prefer to live in clefts but are also found on flat rock surfaces. The sub-belt is not more than 6 inches in vertical height. *Lasaea australis* occurs very plentifully among the byssus strands of the mussel, as do also occasional individuals of the crab *Helice haswellianus* (Whitelegge).

Other species encountered in the belt are *Tetraclita purpurascens* (Wood), *Patelloida marmorata* Gaim., *Patelloida conoidea* Quoy and Gaim. and *Patelloida cantharus* (Reeve).

The density of population of this belt is not very high. *Siphonaria diemenensis* numbering 26 per 30 cm. sq. and *Brachyodontes rostratus* 10 per 10 cm. sq. Where *B. rostratus* does occur it is usually closely packed but the area thus occupied may be very small. The barnacle *Tetraclita purpurascens* is very rare, only one being noted during the examination of the whole platform.

The exposure in the *Patelloid* belt is 8 per cent to 38 per cent in May and 26 per cent to 82 per cent in January. As the belt is only found where there is some wave action the upper limits of exposure are modified by splash.

The lower limit of the Midlittoral is marked by large beds of the mussel *Mytilus planulatus* Lam. These beds occur mainly on the shelf at the seaward

end of the platform (Plate 2). It is possible to collect on these beds only at 'low low' water with a calm sea. Only a few mussels are found in the channels which intersect the platform.

The mussels are closely packed and several layers deep. They form a protective layer to a varied fauna living below them and also serve for the attachment of other sedentary forms. A space of about 1 inch separates the mussels from the rock. The substratum is covered by a thin layer of silt, debris, valves of Lamellibranchs and excreta. The efficiency of the mussels in reducing wave action can be seen from the presence of this fine deposit.

The mussel association may be considered in terms of the epibiose, hypobiose and endobiose of Gislén (1930). The epibiose fauna and flora consists of those forms dwelling on the mussels, the hypobiose is formed of animals dwelling below the mussels and the endobiose comprises a few burrowing forms which live in the silt. To these must be added a few forms dwelling inside the mussels. The hypobiose contains most of the fauna of the mussel beds.

The forms dwelling on the outer surfaces of the mussels are mainly barnacles and algae. The most common barnacles are *Elminius modestus*, *Chthalmus* sp. and *Catophragmus polymerus*. Other species to be found are *Tetraclita purpurascens*, *Elminius simplex* Darwin and *Chamaesipho columna*. The lateral plates of the barnacles living on mussels in the lowest part of the beds have a red-brown microscopic alga living on them. The alga does not form the 'age indicators' as described by Parke and Moore (1935) nor does it appear to be penetrative.

Algae are not common living on the outside of the mussel shells. *Ulva lactuca* L., *Polysiphonia* sps., *Gigartina* sps. and *Laurencia botryoides* (Gaill.) are the most common species to be found. *Ulva* sps. are very frequently found associated with mussel beds in different parts of the world. Cotton (1910) noted that the mussels formed a suitable substratum for this alga.

Inhabiting the algae are several species of annelid worms, mostly of the genus *Nereis* and *Leptonereis*, numerous amphipods, including *Megamoera diemencnsis* Haswell and a tanaid. The tanaid is very common. One small *Polysiphonia* plant about 5 inches in height harboured thirty of these crustaceans.

Dwelling below the mussels are very large numbers of a crab of the family *Porcellanidae (?Petrolisthes* sp.*)*. There are more than 100 individuals of this species to the 30 cm. sq. Various species of amphipods are very numerous. These crustaceans swim in the water when it is still and as soon as a wave comes in they seize hold of whatever firm object happens to be at hand.

The flatworm *Leptoplana australis* Laidlaw is very plentiful in dead mussel shells. As many as 12 have been taken from one shell but not all of the dead shells are inhabited by them.

Other species found below the mussels are *Cominella lineolata* (Lam.), *Patelloida alticostata* Angas, *Patelloida conoidea* Quoy and Gaim., *Venerupsis diemenensis* Quoy and Gaim., *Ostrea virescens* Angas, *Monia ione* Gray, *Helice haswellianus* and a *Cancrid* Decapod. There are also many species which I have not found possible to identify, such as several isopods, three species of anemone and some simple ascidians. It is worth recording that these latter are not *Pyura praeputialis* (Heller).

The endobiose consists of several burrowing worms which live in the silty deposit below the mussels. The only other burrowing form present is *Saxicava australis* (Lam.).

Living inside the mussels are numerous specimens of the pea crab *Fabia hickmani* Guiler. A considerable proportion of the mussels are infected by these crabs (Guiler, 1949). Two specimens of the crab *Halicarcinus ovatus* (Stimpson)

have been found inside mussels. It is thought that this infestation was accidental as the crab is common below the mussels and has also been found on *Corallina*. An amphipod was found on one occasion living on the edge of the mantle of a mussel. Only one specimen was noted in this habitat. Its occurrence there may have been accidental.

The lower limit of the mussels is very sharp. They are replaced by a thick mat of *Laurencia* sps. The conclusions of Kitching (1937) that slow growing perennials choke other forms and eventually dominate colonization of the upper Sublittoral probably apply to the area under consideration.

The depredations of certain non-intertidal echinoderm species are suggested by Newcombe (1935) as the reason for the sudden lower limit of the mussels in some East Canadian beds. In the absence of similar species on the Tasmanian beds the conclusions of Kitching offer the only possible explanation for the sharp delineation of the mussels in Tasmania.

The mussel community can be compared with that described by Newcombe *(loc. cit.)*. The most salient feature is the richness of the algae of the Canadian mussel beds in comparison with the poverty of the Tasmanian beds. Newcombe records 17 species, some of which, such as *Fucus vesiculosus* L. and *Ascophyllum nodosum* Le Jol are very common and rank as co-dominants. The Canadian beds are preyed upon by many more carnivorous types than have yet been found on the Tasmanian beds. The majority of mussel deaths on the former are attributed to starfishes, urchins and *Nucella lapillus* (L.).

It may be noted here that all the mussels in Southern Tasmania are not intertidal. Individuals of the same species as the majority of the intertidal specimens, *Mytilus planulatus*, are found in several fathoms of water, mostly in sheltered bays. The lack of air exposure does not seem to have any deleterious effect on the mussels, though it has been shown by Young (1946) that exposure to air assists spawning.

The time of the year at which the Tasmanian mussel spawns is not known. It may be noted that the North Pacific mussel, *Mytilus californianus*, spawns all the year round with maxima in October and the spring (Whedon, 1936, and Young, 1946).

Mussel beds are not found in sheltered places. Some wave action is essential to the well-being of mussels. Fox and Coe (1943) have shown that finely divided detritus constitutes more than four-fifths of the food of *Mytilus californianus*. In the beds under consideration the sea is rarely completely calm and there is also a quantity of suspended matter brought down by the river. The sea is also fairly rich in coastal plankton. These conclusions could not be applied to dredged mussels from sheltered inlets. The problem there is different due to the lack of algae to restrict growth. There is little wave action to stimulate the mussels but there is usually a considerable amount of suspended matter.

The exposure of the mussel beds varies from 0 per cent to 8 per cent in May to 0 per cent to 27 per cent in January.

(4) The Infralittoral Fringe

The Infralittoral fringe is represented by two distinct types of shore. The exposed end of the platform and the exposed channels at the South end of the platform are both very similar in appearance but the channels at the North end are sheltered from the most severe weather and present a very different facies from the exposed places.

The exposed channels and the edge of the platform are characterized by the sudden appearance of the algae as the dominant type. A dense algal mat of *Laurencia* sps., *Polysiphonia* sps. and several red algae immediately replaces the mussels. As an overcurtain to this there is a forest *Xiphophora* sp., *Macrocystis pyrifera* (Turn.) Agardh. and the ascidian *Boltenia pachydermatina* Herdm. The detailed fauna of these channels and the vertical face of the platform is difficult to examine as there is deep water immediately off the edge of the platform.

The channels on the North side of the platform are all, with the exception of one, short and shallow. The exceptional one crosses the platform from North to South but is very high up on the shore and is only filled at 'low high' and 'high high' tides. There are boulders of varying sizes in the bottom of these channels which furnish protection for a varied fauna.

The great majority of the fauna of the Northern channels falls very sharply into the hypobiose of Gislén. Among these species are *Plaxiphora albida* (Blainville), *Scutus antipodes* Montfort, *Subninella undulatus* (Martyn), *Macrochisma tasmaniae* Sowerby, *Haliotis noevosa* Martyn, *Cominella lineolata* (Lam.), *Patelloida inradiata* (Reeve), *Patelloida conoidea* Quoy and Gaim., *Fusinus novaehollandiae* Reeve, *Halicarcinus ovatus* (Stimpson), *Astacilla derwenti* Guiler (on *Polysiphonia* sp.), *Strongylocentrotus erithrogrammus* (Val.), *Coscinasterias calamaria* (Gray), *Stichopus mollis* (Hutton), *Tosia australis* Gray, *Patiriella calcar* (Lam.), *Patiriella exigua* (Lam.), *Tedania bispinata* Hentschel, *Tethya diploderma* Schmidt, *Hymeniacidon perlevis* (Montagu), *Actinia tenebrosa* Farqu. and *?Oulactis muscosa* Andrés. Among many unidentified species are an *Aplysia* sp., bryzoans, isopods, amphipods, hydroids, a crinoid, tanaids, a *?Petrolisthes* sp. crab, polynoid worms, a tectibranch and an anemone *(Sagartidae)*.

The algae are mainly of several species of *Polysiphonia, Cystophosa, Ulva lactuca, Corallina* sps. and *Lithothamnia*. The term *Lithothamnia* is used to cover all *Lithothamnion*-like forms.

Transect 2

Station	At the North end of Blackman's Bay on the rock platform beside the deep channel.
Date	June, 1948, and various subsequent dates.
Type	Semi-exposed rocky coast.
Maximum wave exposure	*c* (1-8) 2, *b* 3.
Description	The transect runs in a Southerly direction to the sea from the low cliffs at the seaward side of the channel near the road. The platform is of a different nature from that described in Transect 1, since the waves sweep across it in rough weather. The platform has been formed by action at approximately right angles to the dip of the beds.
Geology	Mudstone. The beds are weathered along the strike.
Tidal data	From Hobart Recorder.
Physical environment	As in Parts III and IV.
Zonation	It is not intended to give full details of the zonation and associations of this and the following transects but to concentrate on the differences between the transects and that described above.

The poverty of the population of the upper Midlittoral zone and the Supralittoral fringe is further accentuated in this transect by the absence of a belt of *Bembicium nanum*. At the seaward end of Transect 1 it was seen that the barnacles are immediately replaced by *Melaraphe unifasciata*. This was attributed to wave action. The sweeping effect of the waves across this platform has resulted in the elimination of the zone of *B. nanum*. The probable reason for the lack of toleration of wave action of this species lies in the comparative inability to remain in position under heavy surf or waves. The shell is much larger than that of *Melaraphe unifasciata* and the animal cannot hide in small clefts and so avoid most of the wave forces.

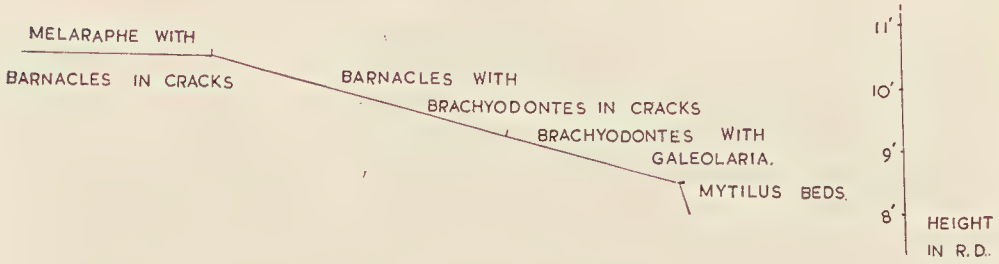

Fig. 28.—Transect 2, South end of Blackman's Bay. Scale as in Fig. 25.

In spite of the increase in wave action over the platform in rough weather compared with that encountered in Transect 1, the levels at which organisms are encountered are very much lower than in that transect (Fig. 28). Some species, such as *Brachyodontes rostratus*, are found high up on the shore living in clefts. The latter species is found at 10 feet 6 inches R.D. It is immediately replaced by *Melaraphe unifasciata* with *Chthamalus* sp. in clefts. The majority of species are found at a lower level than in Transect 1. This general depression of zones can be correlated with the fact that the dessication encountered in calm weather is greater than that met with in Transect 1.

In calm conditions there is little spray or wave action on this platform. The difference of exposure at the edge of the platform at Pinnacle Point as compared with the exposure at this platform is probably in the order of 20 per cent to 40 per cent. There is also a greater exposure to summer sun on this platform and the angle of inclination of the platform is such that the rays of the sun strike the rock at an angle which is nearer to a right angle than on the platform at the other end of the bay. The presence of *Brachyodontes rostratus* at such high levels is a feature for which there is no obvious explanation.

To the seaward edge of this platform is a vertical face of rock which is fully exposed to waves (Fig. 29). The lower part of the barnacle belt is populated by *Melaraphe praetermissa* May. Below this is a thin belt of *Brachyodontes rostratus* which is followed by *Mytilus planulatus*. There is no serpulid belt.

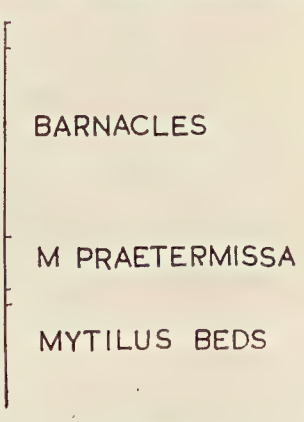

Fig. 29.—Section at seaward end of the platform at Transect 2.

TRANSECT 3

Station	On the second platform North of the Blow Hole at Blackman's Bay.
Date	August, 1948, and various subsequent dates.
Type	Semi-exposed rocky coast.
Maximum wave exposure	*c* (1-8) 2, *b* 3.
Description	The transect runs to seaward from the foot of the high cliffs at the North end of the platform. A deep water channel runs in beside the platform. Where the platform has been worn down to the level of the water in this channel waves sweep on to the platform (Plate 1).
Geology	On West dipping mudstone.
Tidal data	From Hobart Recorder.
Physical environment	As in Parts III and IV of this work.

The salient feature of this transect is the sweeping action of the waves on to the platform at the places where the mudstone has been worn along the bedding planes and has reached the level of the water in the deep channels bounding the platform. The extreme of this is seen at the cliff foot. The end of the deep channel being at the foot of the cliffs there is a 'build up' of water at each wave. This causes a rush of water across the platform at the base of the cliff. Thus we find a modified lower Midlittoral zone at the foot of the cliffs. This zone is populated by *Mytilus planulatus, Catophragmus polymerus, Hormosira banksii, Corallina* sps,, *Actinia tenebrosa* and a few *Galeolaria caespitosa.* The mussels are of average size but do not form beds, preferring to live in clusters. A few *Halicarcinus ovatus* crabs are found among the byssus strands of the mussels. The mussels are found at a height of 11 feet 1 inch R.D., or three feet above those at the edge of the platform. To some degree the mussels are assisted to live at this level by the shelter afforded by the high cliffs which reduce insolation and possibly rainfall. In the transect waves wash the platform in three places which are indicated by the presence of *Coralline* algae.

At the foot of the cliffs the barnacle zone is greatly reduced. Barnacles are only found in clefts and even in this habitat they are rare. The decrease in numbers takes place quite suddenly just above the top of the *Galeolaria* belt at about 12 feet 6 inches R.D. This is due to the very poor splash effect of waves travelling parallel to a cliff face. The effect is further accentuated by the fact that the cliff is undercut to a depth of about 1 foot.

The chiton, *Sypharochiton pellis-serpentis* (Quoy and Gaim.), occurs very plentifully on this platform. In the two previous sections it was found in pools and clefts but here it is dominant on one of the rock faces. It occurs in the *Patelloid* belt.

In the more wave sheltered parts of this platform *Actinia tenebrosa* has become established in the mussel beds. This anemone occupies small areas of rock in the mussel beds which it keeps free of other forms. The anemones must move around the cleared area.

TRANSECT 4

Station	On the rock platform at Perameles Bay.
Date	August, 1948, and various subsequent dates.
Type	Semi-exposed rocky coast.
Maximum wave exposure	*c* (1-8) 2, *b* 3.

Description	The transect runs out from the base of the cliffs to the right of the path down to the shore. Most of the platform is covered by the sea at 'high high' water.
Geology	Mudstone.
Tidal data	From Hobart Recorder.
Physical environment	See Parts III and IV of this work.

It may be noted here that this bay, Perameles Bay, is reached by a steep cliff path which runs down a gully beyond the Blow Hole.

The basic zonation seen on this transect is the same as that seen on Transect 1. Once again, the absence of *Bembicium nanum* is to be noted due to the sweeping action of the waves surging across the platform. The most interesting feature is to be seen at the foot of the cliffs at the landward end of the transect. Here the belt of *Patelloida alticostata* appears above that of *Elminius modestus*. In the actual section the reason for this is not immediately apparent. The belt of *Patelloida alticostata* commences at a height of approximately 12 feet R.D. and ends at 12 feet 6 inches R.D. This would give an exposure in January of 100 per cent which the limpet could not tolerate. The reason for the reversal of zones is to be seen in the general topography of the area to the South of the transect.

A deep channel cuts into the platform in an East to West direction immediately to the South of the transect. This platform ends at the foot of the cliffs. Waves sweep up the channel and cause considerable spray, without the waves themselves covering the base of the cliff. This spray has been sufficiently great to raise the faunal levels. Wave action also will raise the faunal levels but there is an important difference in the effects of the two factors. Spray acts in a differential fashion on the intertidal forms whereas wave action raises the general levels at which the species are to be found. Spray is of little use to plankton feeders in obtaining food and these types will be confined to wave washed areas but browsing species, algae and some carnivores will receive sufficient moisture to live well above the area washed by the waves. In this case the barnacles are limited in their vertical distribution, not by the amount of exposure to which they are subjected, but by the amount of feeding time they have at their disposal. The limpets are limited by the exposure toleration of themselves or their food. In places where wave action is not accompanied by exceptionally heavy spray, the vertical distribution of the intertidal forms is dominated by the wave action, but in places where the spray is greater than might be expected it is the latter that controls the distribution of species on the shore.

Transect 5

Station	On the rocks between Kingston Beach and Blackman's Bay.
Date	August, 1948, and various subsequent dates.
Type	Semi-exposed rocky coast.
Maximum wave exposure	*c* (1-8) 2, *b* 3.
Description	The section is nearly vertical on the first igneous intrusion along the shore from Kingston.
Geology	Dolerite.
Tidal data	From Hobart Recorder.
Physical environment	See Parts III and IV of this work.

In this transect the Patelloid belt is absent. On all of the dolerite outcrop limpets are very rare and do not form a belt at any place. In the transects the serpulid belt is also greatly reduced and in some places it may be absent. When

the serpulid belt is absent barnacles inhabit the space thus made available. In the transect the barnacle belt extends below the mussels and the dominant barnacle is *Catophragmus polymerus*. The density of the population of this species is 18 per 10 cm. sq. This apparent downward extension of barnacle zones is to be seen on all the igneous rock.

The igneous rock shows more diversity of zoning than does the sedimentary. As mentioned above the serpulid belt may be absent but in another nearby place the zoning is as follows:—

Barnacle belt.
Barnacles with *Galeolaria*, all densely packed.
Infralitoral fringe.

It is suggested that the reason for this distribution lies in intense interspecific competition between barnacles, limpets, mussels and serpulids. This will be studied further when the transects are contrasted in the discussion.

The barnacles and serpulids, when present, are all much more closely packed together than on any of the mudstone transects. There is no obvious reason for the greater density of these species, other than the possibility that the dolerite offers a more suitable substratum for sedentary types. The exposure to wave action at this transect cannot be greater than that encountered at Transects 1, 3 and 4. All other physical conditions are very similar. Mudstone may chip or flake off under heavy wave action, whereas the igneous material offers a more stable substratum for colonization.

Transect 6

Station	On a mudstone platform to the South of Kingston Beach and to the North of Transect 5.
Date	August, 1948, and various subsequent dates.
Type	Semi-exposed rocky coast.
Maximum wave exposure	*c* (1-8) 2, *b* 3.
Description	The transect is on the vertical face of a narrow platform at the base of the cliffs to the South of Kingston Beach. The platforms are not covered by the sea except in very rough weather. The zoning has been observed on the almost vertical seaward edge of the platform.
Geology	Mudstone.
Tidal data	From Hobart Recorder.
Physical environment	See Parts III and IV of this work.

This transect was specially chosen to have the same wave exposure as Transect 5. The limpet belt is recognizable but there is no *Galeolaria* belt. Serpulids are present but in small numbers. They are mostly found between the belts of *Mytilus planulatus* and *Brachyodontes rostratus*. The barnacle, *Catophragmus polymerus*, is found in numbers in the *Brachyodontes* belt and this is indicative of the amount of wave action in the area. The barnacle belt is not well developed and individuals do not form a dense population.

Very few individuals of the ascidian *Pyura praeputialis* (Heller) are found at the same level as the mussels. The ascidians are small and only one occurs about every 50 feet of shore.

At one place the mussels formed the substratum for a dense mat of *Ulva lactuca*.

Transect 7

Station	On a large boulder in the bay to the North of Lucas Point.
Date	August, 1948, and various subsequent dates.
Type	Semi-exposed rocky coast.
Maximum wave exposure	*c* (1-8) 4, *b* 3.
Description	The boulder lies to the North end of a stony bay to the North of Lucas Point. The transect is a vertical section down the side of the boulder. The sides of the rock are approximately 8 feet long.
Geology	Tillite.
Tidal data	From Hobart Recorder.
Physical environment	See Parts III and IV of this work.

The zonation exhibited here is very similar to that seen on the mudstone at Blackman's Bay with the exception that there is a well developed band separating the mussel belt from the Infralittoral fringe. Inhabiting this belt are barnacles, *Chthamalus* sp., *Catophragmus polymerus* and *Chamaesipho columna*. The Infralittoral fringe is much richer in *Lithothamnia* than in any other transect. The barnacle belt is not as wide as on the wave-sheltered side of the boulder. Correlated with this is a lowering of the lower limit of *Melaraphe unifasciata*. There are no algae in the mussel belt with the exception of a few small *Ulva* plants.

On small boulders there is a well developed flora and fauna in the Infralittoral fringe consisting of *Macrocystis pyrifera*, *Codium muelleri* Keutzing, *Laurencia* sps., *Ulva lactuca* and *Lithothamnia*. The animals found are *Ischnochiton lineolatus* (Blainville), *Cellana variegata*, *Patelloida alticostata*, *Patelloida conoidea*, *Cominella lineolata*, *Galeolaria caespitosa*, *Catophragmus polymerus* and *Chthamalus* sp. Above this level there are only a few isolated barnacles and the crab *Leptograpsus variegatus* (Fabr.). The crabs run about below boulders and during rough weather are to be found well above the maximum distance reached by the waves on the shore.

Off-shore there is a large bed of kelp. This consists of two species, *Sarcophycus potatorum* (Labill.) Kütz and *Macrocystis pyrifera* (Turn.) Agardh. The width of the kelp bed is variable and it lies between 50 and 100 yards off-shore. The kelp extends from Pierson's Point to near Lucas Point. The presence of this forest is of considerable importance in modifying the intensity of wave action. Several other transects were considered on this stretch of coast. They were all very similar to No. 7 but show a progressive increase of the height of the upper zones on the shore towards Pierson's Point.

Discussion

Taking Transect 1 as an example, the number of species recorded on the shore in terms of Recorder Datum show some interesting points (Table IX). In this table the levels on which the exposures have been calculated are not those on the wave exposed seaward face of the platform. For similar reasons the number of species inhabiting the barnacle belt does not include species living at the end of the platform.

The *Galeolaria* belt has a small number of animals inhabiting it for two reasons. The first reason lies in the fact that the distribution of animals on the shore is bimodal around M.S.L. This level occurs in the middle of the *Galeolaria* belt. This feature of littoral animal distribution was first shown by Colman (1933). The second reason lies in the fact that the belt is frequently

very densely populated by serpulids. I have not found it possible to determine whether this is due to the fact that the space is suitable only for serpulid colonization or whether the serpulids establish dominance over all other forms in a suitable habitat. It is more probable that the worms crowd out other forms.

A feature of the zones, which is not obvious until detailed counts are made, is that, at about the middle of the mussel and *Patelloid* zones, there occurs a falling off in the number of species present. The upper part of the barnacle belt contains species which are to be found higher up on the shore.

TABLE IX

Number of species on the shore in Transect 1 and their relation to tidal levels.

Zone	Number of species	Height in R.D.	Exposure range %	Tidal Levels
Melaraphe	2	Above 11′ 6″	70 to 100	12′ 0½″ H.H.T.
Bembicium	3	11′ 3″ to 11′ 6″	59 to 90	
Barnacle	8	10′ 9″ to 11′ 3″	27 to 88	10′ 11″ L.H.T.
Galeolaria	4	10′ 6″ to 10′ 9″	18 to 71	10′ 7½″ M.S.L.
Patelloid	15	9′ 11″ to 10′ 6″	7 to 60	10′ 3″ H.L.T.
Mytilus	31+	8′ 4″ to 9′ 11″	0 to 26	9′ 1″ L.L.T.
Infralittoral Fringe	36+	Below 8′ 4″	0 to 2	

The existence of 'critical levels' is shown by Table IX. Such levels, based on the numbers of forms inhabitating the shore, exist at about the middle of the mussel beds, the middle of the *Patelloid* belt just above the region of *Brachyodontes rostratus* and at the middle of the barnacle belt at the point where the species found at higher levels are encountered. These levels correspond to the tidal levels of the average annual height of 'low low', 'high low' and 'low high' tides respectively. For the tidal level in the *Mytilus* belt at which a very great diminution in the numbers of the fauna takes places the term 'lethal level' has been proposed (Guiler, 1949).

The distribution of *Galeolaria caespitosa* in relation to intense wave action is of interest. At the seaward end of Transect 1 the belt is fairly well developed (Plate 1) but in this case the full force of the waves is broken by the mussel beds which extend some 15 feet or more out from the worm tubes. In Transect 5, which is fully exposed to wave action, the *Galeolaria* belt may be greatly reduced or absent. On the same igneous rock the worms are very well developed on the wave-sheltered side of the outcrop. The mudstone of Transect 6, with the same exposure to wave action as Transect 5, shows no belt of *Galeolaria* but only occasional individuals. *Galeolaria* does not like wave action and a similar fact has been noted at Sydney by Dakin, Bennett and Pope (1948).

At a place where *Galeolaria* is absent there is, theoretically, a space available for colonization by other forms. There is evidence of intense inter-specific competition between barnacles, mussels and possibly limpets for this space. It has been shown by Hatton and Fischer-Piette (1932) that turbulent water suits barnacle attachment and that a wave exposed area has a dense barnacle population. Further, mussels like turbulent conditions for feeding (Fox and Coe, 1943) so that this species will also find a suitable habitat. Hewatt (1935) shows that on a large barnacle spatfall the limpets are driven further up the shore. On exposed places in Tasmania it is suggested that the limpets are eliminated by the barnacles because they cannot migrate further up the shore on account of their limited exposure toleration. Field evidence of the results of this inter-specific competition is to be seen on Transect 5 where *Galeolaria* dominates the wave-sheltered places to the detriment of limpets, mussels and barnacles. Mussels dominate some of the wave-exposed zones and barnacles dominate others. In the barnacle zones there are always a few mussels. The mussel zones have limpets

and barnacles. The mussels may maintain themselves by eating a sufficient number of cyprid larvae to prevent a successful barnacle settlement, though this is against the findings of Fox and Coe *(loc. cit.)*.

In a wave-exposed area the suitability of the habitat may obscure the bi-modal distribution of the littoral fauna. In an area where there is virtually continuous spray the effect of critical tidal levels may be greatly altered by this.

The presence or absence of *Bembicium nanum* may be considered as an index of the intensity of wave action, the species being usually found in sheltered areas.

A comparison of the levels of the same organisms at different places reflects the intensity of wave action (Fig. 30). In Transects 1 and 7 wave action is most intense while Transect 2 shows the least wave action. Transects 5 and 6 have similar wave action with perhaps slightly greater spray in Transect 6. This diagram serves to emphasise that only a theoretical exposure can be obtained from tidal levels on an exposed coast. The amount of spray is the controlling factor. At 11 feet R.D. *Galeolaria*, barnacles or *Melaraphe* may be

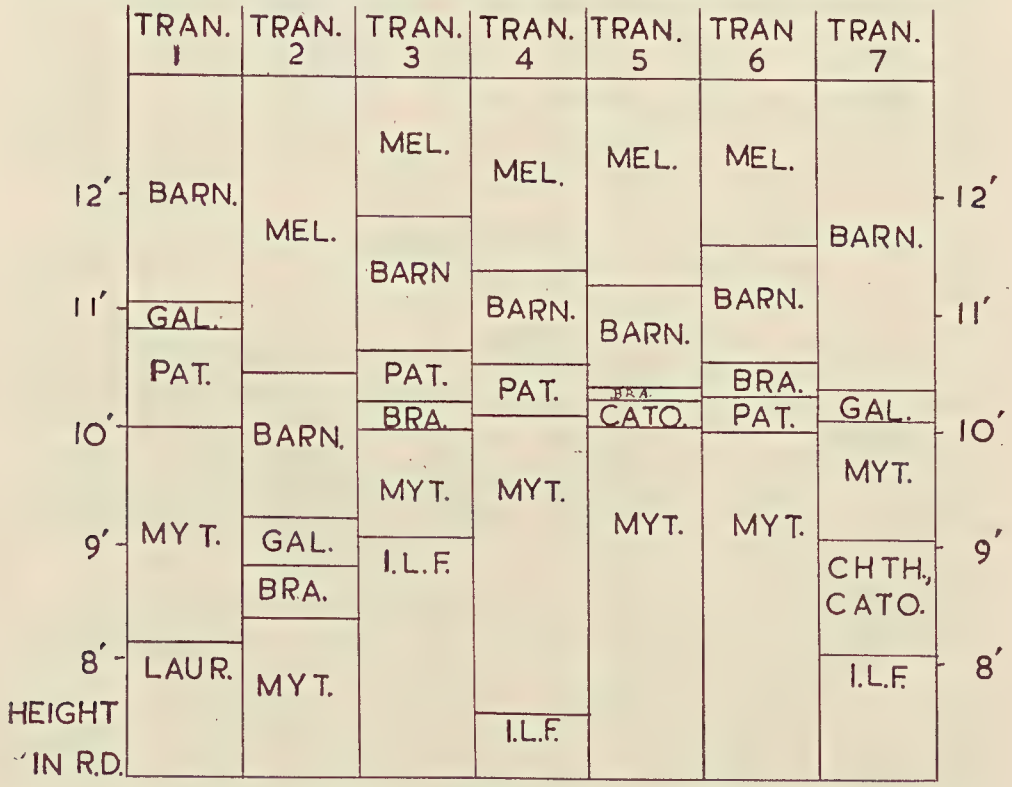

FIG. 30.—Comparison of the faunistic levels of Transects 1 to 7. The abbreviations used are:—BARN., barnacles; BRA., *Brachyodontes rostratus*; CATO., *Catophragmus polymerus*; CHTH., *Chthamalus* sp.; GAL., *Galeolaria caespitosa*; I.L.F., Infralittoral fringe; LAUR., *Laurencia* sps.; MEL., *Melaraphe unifasciata*; MYT., *Mytilus planulatus*; PAT., *Patelloid*.

encountered, depending on the intensity of wave action and the amount of spray. It is possible to use this fact as a means of obtaining an expression for the relative amounts of spray to which various places in an area are subjected. It is more accurate to consider this factor as an index of spray than of wave intensity, because the prevailing wind may alter the amount of spray without altering the amount of wave action.

To obtain this factor it is necessary to have available full tidal data for the area under examination and to have studied a number of transects in the area. The average upper limit for a species in the area is calculated in inches above C.D., or in this case R.D. The upper limit of the species at a specific place is then expressed as a factor of the average. The average upper limit of *Mytilus planulatus* in the Blackman's Bay area is 9 feet 9 inches R.D. and at Transect 2 the mussels are found at 8 feet 6 inches R.D. The spray encountered in this area is thus 102/117. By using the level of the upper limit of one species at two places a comparative figure can be derived as a ratio. *Galeolaria* at Transects 1 and 3 shows a spray intensity ratio of 133 : 111.

It is difficult to contrast the zonation at Blackman's Bay with that shown in other parts of Australia. Fischer (1940) has stated that the *Galeolaria* and *Melaraphe* zones at Hobart are comparable with those at Sydney. It is worthy of note that *Galeolaria* has a greater vertical range at Sydney than at Hobart. This may be due to the greater tidal range at the former place but in the absence of a correlation of animal zones with tidal levels it is impossible to decide this point. Fischer also makes a comparison of the zonation at exposed and less exposed points on the coast of New South Wales. This is of interest as showing the reversal of the *Cellana-Chthamalus* zones at two points, the barnacle being the lower at the less exposed place. This may be due to relatively heavier spray. The zonation at Sydney shows many points of resemblance to that found at Blackman's Bay. An important difference lies in the replacement of the Tasmanian mussel beds by *Pyura*.

The relation of the zones recognized in Australia by various workers to the classification suggested by Stephenson and Stephenson (1949) may be summarised as in Table X.

NEW SOUTH WALES		QUEENSLAND	S. AUSTRALIA	S. TASMANIA	UNIVERSAL
HEDLEY, 1915.	D., B. & P., 1948.	JOHNSTON, 1917.	EDMONDS, 1948.	GUILER, 1949.	S. & S., 1949.
UPPER ZONE WITH TECTARIUS	SUPRALITT. WITH MELARAPHE.	TECTARIUS & UPPER MELARAPHE ZONES.	SUPRALITT. WITH MELARAPHE.	SUPRALITT FRINGE WITH MELARAPHE.	SUPRALITT. FRINGE WITH LITTORINIDS.
CHTHAMALUS MELARAPHE TETRACLITA.	UPPER LITT. WITH BARNACLES.	LOWER MEL. OR CHTHAMALUS.	BARNACLES.	BARNACLES.	MID LITTORAL.
MEDIAN ZONE WITH GALEOLARIA.	MIDLITT. WITH GALEOLARIA.	TETRACLITA	MOLLUSCS & GALEOLARIA.	GALEOLARIA PATELLOID. MYTILUS.	
LOWER ZONE WITH CYNTHIA.	LITT.-SUBLITT. FRINGE WITH PYURA.	SARGASSUM,	SUBLITT. FRINGE WITH CYSTOPHORA.	INFRALITT. FRINGE WITH LAURENCIA ETC.	INFRALITT. FRINGE WITH LAMINARIA ETC.

TABLE X.—Relation of intertidal zones recognised by Australian authors to those proposed by Stephenson and Stephenson (1949). The abbreviations used are are INFRALITT., Infralittoral; LITT.-SUBLITT., Littoral sublittoral; MEL., *Melaraphe*; SUPRALITT., Supralittoral; UPPERLITT., Upperlittoral.

Note that Fischer (1940) followed the classification of Hedley (1915).

Although the index species of the Midlittoral zones in Tasmania are similar to those of other parts of Australia the deficiency of algae in Tasmania is to be noted both from text descriptions and photographs.

The absence of *Pyura* on exposed coasts in both South Tasmania and Queensland is probably due to the species approaching the extremities of its geographical range.

It can be concluded that there exists a lethal tidal level at which there occurs a very great reduction in the number of species inhabiting the shore. It is also shown that there is a bimodal distribution of intertidal species with a minimum at M.S.L. The presence of diurnally unequal tides does not complicate the critical tidal levels.

(g) Colonization of Rock Surfaces

Small scale experiments were carried out in an attempt to ascertain the sequence of colonization of bare rocky surfaces on the shore in the region of Pinnacle Point at the South end of Blackman's Bay. Blackman's Bay was chosen as the area in which to conduct the experiments because it could be visited at frequent intervals, is easy of access and its fauna is reasonably well known.

In order to throw some light on the poverty of the fauna of the Midlittoral zone the experiments were carried out in that region in the lower part of the barnacle and the upper part of the *Galeolaria* belts.

Literature

Work has been carried out in various parts of the world on the problems of intertidal colonization. In some cases the workers have been concerned with the colonization of new rock surfaces and in others the emphasis has been placed on the recolonization of denuded rock rurfaces. In Britain, Kitching (1937) and Pyefinch (1943) have been concerned with the latter aspect. In France, Fischer-Piette (1929 and 1932*b*), Hatton and Fischer-Piette (1932) and Hatton (1932) have studied the general aspects of the problem. Much work has been done in America on the season of attachment of sedentary marine organisms and their rates of growth. Among the American authors whose work bears on the recolonization problem are Visscher (1928), Visscher and Luce (1928), Pierron and Huang (1926), Coe (1932), Graham and Gay (1945) and Wilson (1925).

The colonization of new surfaces has been studied by several European workers. In many instances advantage has been taken of public works to supply the new surfaces. Brandt (1897) studied the colonization of the Kiel Canal, Herpin (1935*a* and 1935*b*) observed the colonization of beaches and wrecked ships and Rees (1940) noted the succession on a new sewage outfall. Moore (1939) and Moore and Sproston (1940) described the sequence of colonization of a new sea-wall at Plymouth.

Experiment 3.—To obtain a knowledge of the sequence of colonization of a bare rock in the Midlittoral zone.

Method of Experiment

Two rocks were chosen for the experiment. One was of dolerite and the other of mudstone. Both had to be of sufficient weight to remain stationary under conditions of the most intense wave action experienced in the site chosen. The rocks were approximately 1 foot cubes.

The rocks were examined ten times over a nine-month period. Each face of the rock was examined in detail and the results of these examinations were plotted on full size, or half size, reproductions of the faces of the rock. This simplified identification of previously recognized individuals.

In order to avoid crushing any forms dwelling on the bottom surface of the rocks a smaller rock was utilised for bottom surface examinations. This smaller rock was placed beside the larger rocks and only the fauna on the under side of it was examined. The rock was placed in such a position that the under surface of it was free from the substratum.

The experiment would have been continued for a longer period than nine months, if it had not been for the fact that the rocks were thrown into deep water by some unknown persons. I do not consider that wave action was responsible for the loss as during the period the rocks disappeared there were no gales of greater severity than had already been experienced.

The site selected was in a channel on the North side of the platform at Pinnacle Point at the South end of Blackman's Bay. The channel is completely uncovered at 'low low' tide and has a varied and numerous population. Wave action is not strong, the maximum being *s* (1-7) 1, *b* 2. Under certain conditions of bad weather heavy surf crashing across the platform pours into the channel but the force is mostly spent by the time it reaches the channel and the rock is only subjected to a cataract of water.

The channel was inhabited by *Hymeniacidon perlevis*, *Actinia tenebrosa*, *Elminius modestus*, *Chthamalus* sp., *Ibla quadrivalvis*, *Corallina* sps., *Hormosira banksii*, *Amaurochiton glaucus*, *Patelloida conoidea* and *Galeolaria caespitosa*.

Description of the Rocks Selected

It was originally intended to use rocks of dolerite and mudstone in different parts of the shore but pressure of other work restricted the experiment to the one site with two rock types. The rocks were put in position simultaneously, but the mudstone rock only remained in position for three weeks and then vanished. The rock was not replaced as strictly comparable results could not be obtained with a rock placed in position at a later date. The value of the experiment is not very great but it is included here as several points of interest are raised by the colonization processes.

The dolerite rock was selected from a pile of this rock lying above high water mark on the beach at Sandy Bay. The rock was removed to the laboratory and thoroughly scrubbed with hot water. Chemicals were avoided in this process to avoid reactions with the minerals of the rock. The rock was left to weather for a few weeks after which it was put in position. The smaller rock for the bottom surface experiments was similarly treated. The larger rock was known as Winter Rock A and the smaller as Winter Rock B.

The nature of the rock faces and their orientation can be best expressed in Table XI.

Table XI

Nature and area of the faces of Winter Rocks A and B.

Smooth, sea-sheltered vertical face with vertical and inclined ridges	Landward, 419 sq. cms.
Smooth, sea-exposed vertical face with exposed vertical and inclined ridges	Seaward, 494 sq. cms.
Semi-exposed vertical face with inclined and vertical ridges	Left hand, 637 sq. cms.
	Right hand, 708 sq. cms.
Sea and air-sheltered horizontal face with lateral ridges	Bottom, 271 sq. cms.
Sea and air-exposed horizontal face with lateral ridges	Top, 432 sq. cms.

The experiment was commenced on 18th April, 1948, and observations were made on 1st May, 12th May, 19th May, 29th May, 20th June, 26th June, 3rd July, 8th July, 15th July, 21st July, 14th August, 29th August, 21st September, 19th October, 3rd December, 10th January, 15th February. On the latter date only the bottom face of Winter Rock B was examined.

The first sessile organism to appear on the rocks was a small *Corallina* sp. on the landward face in May. Previous to this several errant species were seen on the faces of the rock, notably *Amaurochiton glaucus* (Gray), *Patiriella exigua* (Lam.), *Cominella lineolata* (Lam.) while below the rocks crabs *(?Petrolisthes* sp.*)* were sheltering. Amphipods were found in cracks on the rock. The first occasion on which large numbers of colonizing animals were noted was in June when 113 individuals appeared on the rocks. There were only 9 deaths noted during this period. Of these new individuals over 72 per cent were *Galeolaria*. These tubes were not confined to the lower part of the rock. About 25 per cent of them were found on the top surface. Barnacles appeared at the same time as the worms but in fewer numbers. A colonial diatom association, mainly of *Euschizonema* and *Melosira* sps. appeared at this time. These colonies were of a very short lived nature only two extending from one week to the next. These diatoms are discussed in section *(h)* below.

There were no macroscopic forms other than barnacles, *Galeolaria* and *Corallina* to successfully colonize the rock. *Actinia tenebrosa, Patelloida alticostata, Patelloida conoidea* and two errant annelids appeared but soon wandered away again. There was a constantly changing number of *Amaurochiton glaucus* on the rock. Several of these were marked and one was noted as returning to the rock at 2, 5 and 3 week intervals.

Table XII shows the number of new individuals settling each month and the number of deaths per month on each of the faces of the rocks. Although during certain months the rock was visited more frequently than others, thus giving a greater number of new settlements, there is no doubt that some faces of the rock were more densely populated during some months than others. The figures, although they show an overall increase of deaths and settlements during the more frequently visited months, reflect the true picture of the trends by the ratio of these numbers.

TABLE XII

The new settlings per month on each face of Winter Rock A and B.

	MAY		JUNE		JULY		AUGUST	
	Settlings	Deaths	Settlings	Deaths	Settlings	Deaths	Settlings	Deaths
Top	1	....	23	....	38	33	2	26
Seaward face	....	....	7	....	14	12	2	5
Landward face	1	....	1	2	26	10	4	18
Right-hand face	....	....	9	....	52	14	14	39
Left-hand face	....	....	31	....	11	37	2	6
Bottom	....	....	42	7	51	29	7	37
	SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER	
Top	5	1	4	4	?	?	....	4
Seaward face	3	....	4	5	?	?	19	6
Landward face	2	....	5	1	?	?	2	6
Right-hand face	19	6	15	13	?	?	11	19
Left-hand face	2	0	3	3	?	?	1	2
Bottom	7	6	33	6	?	?	8	36
	JANUARY		FEBRUARY					
Bottom	5	13	8	6				

Table XIII and Fig. 31 shows the total number of individuals inhabiting the faces each month, while Table XIV and Fig. 32 show the new settlings and deaths of the various species per month.

From these tables and graphs it can be seen that there is a very great decrease in the total number of organisms on all faces between July 21st and August 14th and also between October and December. If the trends shown by the bottom face of Winter Rock B are true (Table XII) there is also a sharp diminution of numbers in December and January.

TABLE XIII

The total number of individuals of all species inhabiting the various faces of Winter Rocks A and B each month for the period June, 1948, to December, 1948.

	June	July	August	September	October	November	December	Totals
Top	23	27	3	7	7	?	3	70
Seaward face	....	9	6	9	8	?	21	53
Landward face	1	16	2	4	8	?	4	35
Right-hand face	9	47	22	35	37	?	27	177
Left-hand face	31	5	1	3	3	?	4	47
Bottom	35	57	27	28	55	?	27	229
Grand Totals	99	161	61	86	118	?	86	611

The bottom face only during January and February had 19 and 16 inhabitants respectively giving an absolute total of 646 organisms noted. These latter figures are not included in the table as they are only indications and may not be true records of actual populations.

TABLE XIV

Total number of specific settlements and deaths per month.

Settlements	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Total
Barnacles	....	18	57	16	24	33	?	24	2	3	177
Serpulids	....	81	130	12	11	14	?	1	3	3	255
Anemones	....	1	....	1	....	....	?	2	....	....	4
Diatoms	....	10	17	2	....	....	?	....	....	....	29
P. alticostata	....	...	....	....	1	3	?	....	....	....	4
P. conoidea	....	....	....	....	....	1	?	3	....	....	4
Patella ustulata	....	....	....	....	....	1	?	....	....	....	1
Corallina	1	2	....	....	....	....	?	6	....	....	9
Nereids	....	1	2	....	....	....	?	....	....	....	3
Red algae	....	....	1	....	....	....	?	....	....	....	1
Chiton eggs	....	....	.	....	3	....	?	....	....	....	3
Totals	1	113	207	31	39	52	?	36	5	6	490
Deaths											
Barnacles	....	3	13	26	1	10	?	45	13	7	118
Serpulids	....	3	94	90	13	19	?	18	....	1	238
Anemones	....	1	....	....	1	....	?	....	....	....	2
Diatoms	....	1	23	5	....	....	?	....	....	....	29
P. alticostata	....	.	....	....	....	....	?	3	....	....	3
P. conoidea	....	..	....	....	....	....	?	1	....	....	1
Patella ustulata	....	.	....	....	....	....	?	1	....	....	1
Corallina	....	1	....	....	....	....	?	....	....	....	1
Nereids	....	..	2	....	....	....	?	....	....	....	2
Red algae	....	....	1	....	....	....	?	....	....	....	1
Chiton eggs	....	..	.	..	....	3	?	....	....	....	3
Totals	....	9	133	121	15	32	?	68	13	8	399

The number of forms successfully settling also shows a sharp diminution in August and January. The number of deaths in July and August is very high. The large number of settlings in July possibly came from a late autumn spawning.

The seaward and landward faces of the rock never had as dense a population as the other faces.

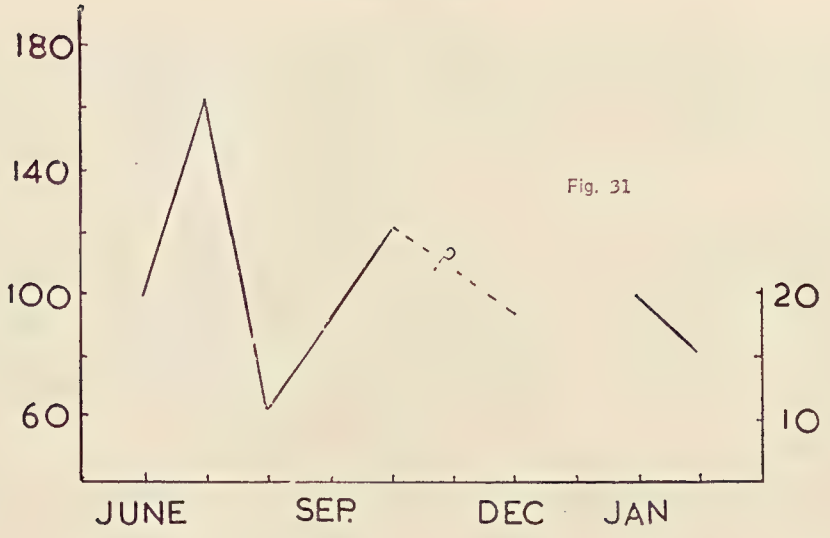

Fig. 31

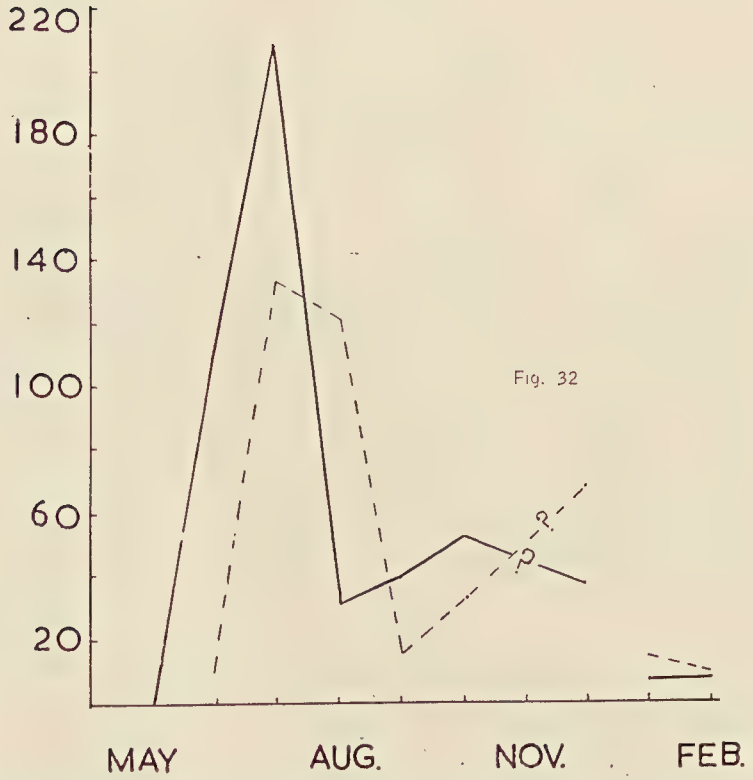

Fig. 32

FIG. 31.—The total number of individuals inhabiting Winter Rocks A and B from June, 1948, to February, 1949.

FIG. 32.—The number of settlements and deaths per month on Winter Rocks A and B.

Discussion

From the above observations it can be seen that the rate of successful colonizing is very slow compared with the rate in other parts of the world where there is a much greater density of population per unit of time. It is proposed to examine some of the factors which may influence the settling of larvae on the experimental rocks.

There is a close correlation between the critical months for intertidal organisms as deduced from physical data in Part 4 of this work (see page 155) and the observed rates of settling and deaths on the experimental rocks. December, January and July are considered to be critical months for intertidal organisms due to the combination of adverse tidal and meteorological factors. April and October are regarded as months of slightly less strain due to the equinoctial change of tidal behaviour. From Tables XII and XIII it can be seen that there are times of high casualties and low spatfall between late July and early August and in October and December. It is further indicated by Winter Rock B (Tables XII and XIII) that January is also a month of stress, though this is not conclusive. March and April unfortunately are not included in the experiment for the reasons given above.

The black colour of the rock would certainly assist barnacle settling. The larvae being negatively phototropic (Visscher, 1928) would choose a dark surface in preference to the surrounding lighter coloured mudstone. The relative absence of surf would tend to reduce the number of successful barnacle settlings though it has been shown by Coe (1932) that test blocks exposed to heavy surf were cleared of barnacles measuring up to several millimeters in diameter. In the channel in which the experimental rocks were situated there was not nearly as great a barnacle population as there was on the exposed edge of the rocky platform. On the other hand, the seaward face of Winter Rock A, which would experience whatever wave action there might be, had very few barnacles on it. It had a very much smaller number than either of the lateral faces. In general, it might be concluded that the channel was not very highly suited to barnacle life, though barnacles were living there.

The poverty of barnacles on the seaward face of Winter Rock A is possibly explained by the fact that the face was towards the North, i.e., it was exposed to the sun. This would drive cyprid larvae round to the sides of the rock where they would find more congenial conditions. Any larvae which had settled on the seaward face would probably be killed by the sun before the metamorphosis was complete. The right hand face, because it is sheltered from all but the early morning sun, has a comparatively rich fauna.

It has been shown by Hopkins (1935) that oysters tend to form their densest colonies on the under surface of objects. The reason for this lies in the larval method of swimming with the velum upwards. There is little evidence of this behaviour being shown by any of the larval forms encountered during the experiment.

It has been noted by Coe (1932) that the degrees of roughness of surfaces influences the population inhabiting them. In this case the faces of the rock were all of equal smoothness and the factor is not applicable to the fauna of different rock faces.

The absence of any algal grazers permanently dwelling on the rocks points to the fact that an algal film was not formed on the rock. This may have been influenced by bacteriological factors (Zobell and Allen, 1935).

The failure of organisms to colonize the rocks is due to the integration of a number of factors. The orientation and siting of the rock and the relation of the faces to sun and wave exposure play some part. The lack of full wave action would reduce the number of barnacle settlements but ought to increase the number of *Galeolaria* settlements. The number of settlings by the worms was large but the death rate was also high. The high death rate was caused by the larvae settling in June or July and being unable to become established before the critical month of July.

Barnacle larvae settled throughout the year. This is in contrast to the situation described by Moore (1939). The critical months also caused a high death rate in this species. In no sense was a pioneer community established as described by Rees (1940). The nearest parallel to colonization in South Tasmania is that described by Pyefinch (1943) who found that no inter-specific competition existed.

(h) Diatom Colonization

During the winter of 1948 a diatom growth appeared on the shores of the Derwent Estuary. It was first noted on the shore on 12th June, 1948, when it appeared quite suddenly. By the 26th of June it was very plentiful in pools and on stones in the lower tidal areas. The diatoms formed filamentous growths on the shore in patches up to 12 square feet in area. Most of the diatoms were *Euschizonema* and *Melosira* sps. From the evidence shown on the experimental rocks it would appear that the life of each aggregation of colonies is short, lasting only about a week.

From June until the 20th August the diatom growths increased until most of the shore up to the *Bembicium* zone was covered with a brown slime. The exposure experienced by the diatoms at this level was 70 per cent in August. During June and July the exposure was 82 per cent and 68 per cent respectively. By the middle of September the diatoms were disappearing. Exposure during this month was 83 per cent.

Where the diatoms formed a more or less permanent mat on the shore a secondary algal association appeared. The algae only appeared where there was no interval of time separating the death of one diatom colony from the appearance of the next. The most common alga to appear was *Ulva lactuca* and this was followed by several small red algae *(Gelidium* sp.*)* and some small *Hormosira banksii.* On the extermination of the diatoms in September the reds and *Hormosira* disappeared very soon afterward, but the *Ulva* remained for two or more weeks. During this time the *Ulva* became bleached.

The effect of this increase of vegetation on animal life on the shore was not very marked. This is probably due to the fact that the change was so short lived. There was some increase in the number of *Bembicium nanum* while *Cominella lineolata* was found further up the channels than it normally occurs. The latter species, from observations in aquarium tanks, does not willingly leave water. There was no apparent change in the number of barnacles on the shore.

The reason for the appearance of the diatoms is not at all clear. They appeared during the most rigorous months of the year and when the exposure to which they were subjected was above 80 per cent. Insolation was most deleterious in its effect on the diatoms. During a warm sunny day at Kingston the sun-exposed rocks were rapidly cleared of diatoms whereas the shaded rocks were still coated with the slime. Recolonization was very rapid either from other stock or by regeneration of the old material.

The disappearance of the diatoms might be correlated with an increase in the number of sun hours and a warming up of sea and air temperatures.

There was no similar growth during the winter of 1949.

Summary

In this paper the general status of marine ecology in Australia is discussed and the literature reviewed. The physical environment in South Tasmania is described in detail, the tides receiving particular attention. As a result of this treatment it is shown that July, December and January are critical months for shore animals. This is verified by some experiments carried out on the colonization of bare rocks. The zonation is examined in the Blackman's Bay area and compared as far as possible with that in other parts of Australia. A factor for comparing the intensity of wave action is given, also a spray intensity factor. The colonization of rocks is shown to depend on a number of factors, mainly sun and wave exposure and the relation of spatfalls to the critical months. An evanescent diatom colonization of the shore is described.

Acknowledgments

I am indebted to Professor V. V. Hickman for checking the typescript of this article and also for his interest throughout the preparation of the material. I also thank Dr. J. Pearson for his interest and suggestions in the presentation of the matter. My thanks are also due to Captain Bowerman for permission to use the records of the Hobart Tide Recorder and to the Weather Bureau, Hobart, for most of the meteorological data. Dr. M. Burton of the British Museum kindly identified some sponges for me and Professor H. N. Barber identified some of the algae and the diatoms. I am also grateful to my wife for assistance in the typing and checking of this work.

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PLATE I

FIG. 1.—The barnacles at the seaward end of Transect 1. The *Galeolaria* tubes can be seen at the bottom of the photograph. The scale is one foot in length.

FIG. 2.—Transect 3, Perameles Bay, at a 'high high' tide.

Fig. 1

Fig. 2

PLATE II

FIG. 1.—The mussel beds at the end of Transect 1. The seaweed is *Macrocystis*.

FIG. 2.—Transect 1, Blackman's Bay. The dark line at the seaward end of the transect is the mussel beds.

Fig. 1

Fig. 2

Pap. & Proc. Roy. Soc. Tasmania, 1949 (15th September, 1950)

A Further Note on the Female Urogenital System of *Hypsiprymnodon moschatus* (Marsupialia)*

By

Joseph Pearson

(Read 1st November, 1949)

With 4 Text Figures

Three years ago a note was published in this Journal (Pearson, 1946) on the condition of the female urogenital system of *Hypsiprymnodon moschatus* Ramsay, 1875. The material then examined was in the possession of the Anatomy Department, University of Sydney, and had already been dissected and had formed the subject of an unpublished thesis by Dr. F. R. Heighway (Mrs. Abbie).

Dr. Heighway's dissection showed that the vaginal cul-de-sac ended some distance anterior to the junction of the two lateral vaginae, a primitive condition hitherto not known in the rat-kangaroos.

But it was clear that this important departure from the normal condition, based as it was upon the dissection of a single specimen, needed confirmation when other material became available, and that such a re-examination would have its greatest value if based upon the study of serial sections.

It was a fortunate circumstance, therefore, that during a recent visit to the U.S.A. I was able to examine one female specimen of *Hypsiprymnodon* in the collection of the American Museum of Natural History, New York, and still more fortunate that permission was obtained to remove the urogenital organs of this specimen for the purpose of making a complete series of transverse sections. These serial sections were made in the Tasmanian Museum, Hobart, and future investigators will be able to examine these sections in the American Museum of Natural History where they will be deposited after the present examination has been completed. An opportunity has thus been afforded of making an accurate reconstruction of the entire urogenital system of *Hypsiprymnodon* and I am indebted to Dr. Anthony, Chief of the Department of Mammals in the American Museum of Natural History, for the permission which was so readily given and to Dr. Tate of the Department of Mammals for his helpful co-operation.

In passing, it may be noted that it required a period of over sixty years to elapse after the publication of Ramsay's diagnosis of this important new genus and species (Ramsay, 1875) before the first scientific examination of the female urogenital system was made by Dr. Heighway. This in itself is a fitting commentary on the inadequate field methods which were in practice until recent times and the lesson needs to be taken to heart by many museum collectors who are still content to preserve only the skins and skeletons of even the rarest mammals.

* The investigations dealt with in this paper have been assisted by a grant provided equally by the Trustees of the Commonwealth Science and Industry Endowment Fund and the Tasmanian State Government.

The specimen which forms the subject of the present note bore the A.M.N.H. number 1812 and had the following dimensions:—

Head and body, 235 mm.
Tail, 130 mm.
Pes, 57 mm.
Ear (from crown), 27 mm.
Ear (from notch), 29 mm.

The presence of two large functional nipples in the pouch justifies the assumption that the specimen was a parous female, but the measurements indicate that it had not attained full size. Though well preserved, it had not been specially fixed for histological examination. It was decided, therefore, to cut relatively thick sections (20μ), as the main purpose of the inquiry was to trace the vaginal system throughout its entire course and, in particular, to observe whether the cul-de-sac was abbreviated as in the Sydney specimen.

The disposition of the vaginal system is clearly indicated in fig. 1 (dorsal view) and fig. 2 (lateral view). A general description of the urogenital system has already been given in an earlier paper (Pearson, 1946), but it is necessary to re-examine certain features of the vaginal cul-de-sac and the lateral vaginae.

It should be said, however, that the two specimens so far examined differ materially from each other in the appearance and shape of the anterior vaginal expansion and cul-de-sac. This is made clear by comparing figs 1 and 2 in the present paper with the illustrations of the vaginal system of the Sydney specimen given in my earlier paper (Pearson, 1946, p. 17, figs 4 and 5). In the New York specimen the anterior vaginal expansion is triangular in its dorsal aspect with its apex pointing anteriorly, whereas in the Sydney specimen this expansion is in the form of a somewhat rectangular chamber about twice as broad as deep. The New York specimen has obviously been subjected to considerable dorso-ventral pressure so that the chamber has been flattened to such an extent that its width is exaggerated and its cavity almost occluded. I have thought it advisable to represent this condition in the reconstructed drawings. Fig. 3 B has been modified to show the anterior vaginal expansion as an expanded structure in one plane, though it is really folded to a considerable extent by the pressure of the surrounding organs so that in transverse section the chamber is V-shaped, the apex of the V being ventral.

The cul-de-sac in the New York specimen also suffers from this dorso-ventral flattening and its short and wide appearance seen in fig. 1 differs greatly from the long, narrow structure described in the Sydney specimen.

In my opinion, the condition of the Sydney specimen probably gives a more faithful picture of the normal arrangement of the vaginal complex in *Hypsiprymnodon*. Nevertheless, it is important to give a description of the urogenital organs of the second female specimen of this rare genus, flattened and distorted though the organs may be through post-mortem pressure.

Cul-de-sac *(m.v.c.)*

The main purpose of the present inquiry was to ascertain whether the cul-de-sac is abbreviated, as Dr. Heighway's dissection showed. An examination of the serial sections establishes without a shadow of doubt that the cul-de-sac terminates a distance of 12 mm. in front of the junction of the two lateral vaginae

and thus bears out Dr. Heighway's findings. As stated above, the cul-de-sac of the New York specimen is expanded laterally and flattened dorso-ventrally, while in the Sydney specimen it is more or less cylindrical in transverse section. The confirmation of the primitive nature of the cul-de-sac in mature females of *Hypsiprymnodon moschatus* gives further support to the view that this species is the least specialized of the rat-kangaroos. In our view, it is the most impressive testimony on this question which has yet been produced and adds considerable strength to the evidence of teeth, simple stomach, and of the persistence of the hallux and digital pads in the pes.

The cul-de-sac can be conveniently divided into two parts; the anterior, which forms the median portion of the anterior vaginal expansion 9 mm. in length, and the posterior portion which is a median posterior prolongation of the vaginal complex 6 mm. long and 4 mm. broad.

As is the case in all marsupials, the right and left vaginae remain separate for a considerable period, but in all rat-kangaroos, including *Hypsiprymnodon*, the septum separating the two culs-de-sac breaks down before maturity is reached, though slight vestiges of the septum can still be seen in mature specimens, both dorsally and ventrally, throughout the entire length of the cul-de-sac (fig. 4).

In this way a capacious chamber, the anterior vaginal expansion *(a.v.e.)*, is produced lying anterior to the lateral vaginae. This chamber is a characteristic feature of the vaginal system of the rat-kangaroos and is composed of the anterior portion of the cul-de-sac (median) and the swollen derivatives of the anterior vaginal canals, situated laterally (see Pearson, 1950, figs 9-12). In the New York specimen the anterior vaginal expansion measures 9 mm. in length and 9 mm. in maximum width.

Lateral Vaginae *(l.v.)*

It should be noted that, whereas the cul-de-sac and anterior vaginal expansion have thin walls, the lateral vaginae and their posterior extension, the posterior vaginal sinus, have relatively thick muscular walls. The actual channel of each lateral vagina is extremely narrow with an average diameter of 400-600μ. The most significant feature in the New York specimen is the almost complete occlusion of the lateral vaginae for a distance of about 3 mm. half way along the course of each duct. In the course of the present work it has been found that all marsupials so far examined pass through an early stage in which the posterior region of each Müllerian duct is separated from the urogenital sinus by a solid rod of cells. Baxter (1935) noted this condition in the early development of the female tract of *Didelphis* and designated this rod of cells the 'sinus cord', a product of the epithelium of the sinus horn. This has been confirmed by the present writer and will be discussed in a subsequent paper. But the occlusion which is mentioned above would appear to be of an entirely different nature and has been discussed by Hill and Fraser (1925) and others. It may be said, too, that we have found occlusion of the lateral vaginae in at least one parous female specimen of *Dasyurus* as well as in the present case which, as already stated, is probably a parous female. In addition, several large but immature specimens of *Dasyurus*, *Bettongia*, and *Protemnodon* show a well-defined occlusion in each lateral vagina. These temporary occlusions may be a phase in the oestrous cycle when the vaginal epithelium is affected by the sex hormones. This is a matter on which evidence is now being collected.

Summary

A re-examination of the female urogenital system of the rare genus *Hypsiprymnodon* was made for the purpose of testing the condition of the cul-de-sac by means of serial sections. This has confirmed Dr. Heighway's claim that the cul-de-sac was abbreviated, and has strengthened the view that this genus is the most primitive of the rat-kangaroos. At the same time, it has demonstrated the close relationship of *Hypsiprymnodon* to other members of the Potoroidae by reason of its highly specialized female urogenital system.

Explanation of Figures

a.v.e.—anterior vaginal expansion
bl.—bladder
cl.—clitoris
l.v.—lateral vagina
m.v.c.—median vaginal cul-de-sac
oc.l.v.—occluded part of lateral vagina
os.u.—os uteri
p.v.s.—posterior vaginal sinus
r.ur.—right ureter
r.ut.—right uterus
u.g.s.—urogenital sinus
u.o.—opening of urethra into urogenital sinus
ureth.—urethra
ut.n.—uterine neck

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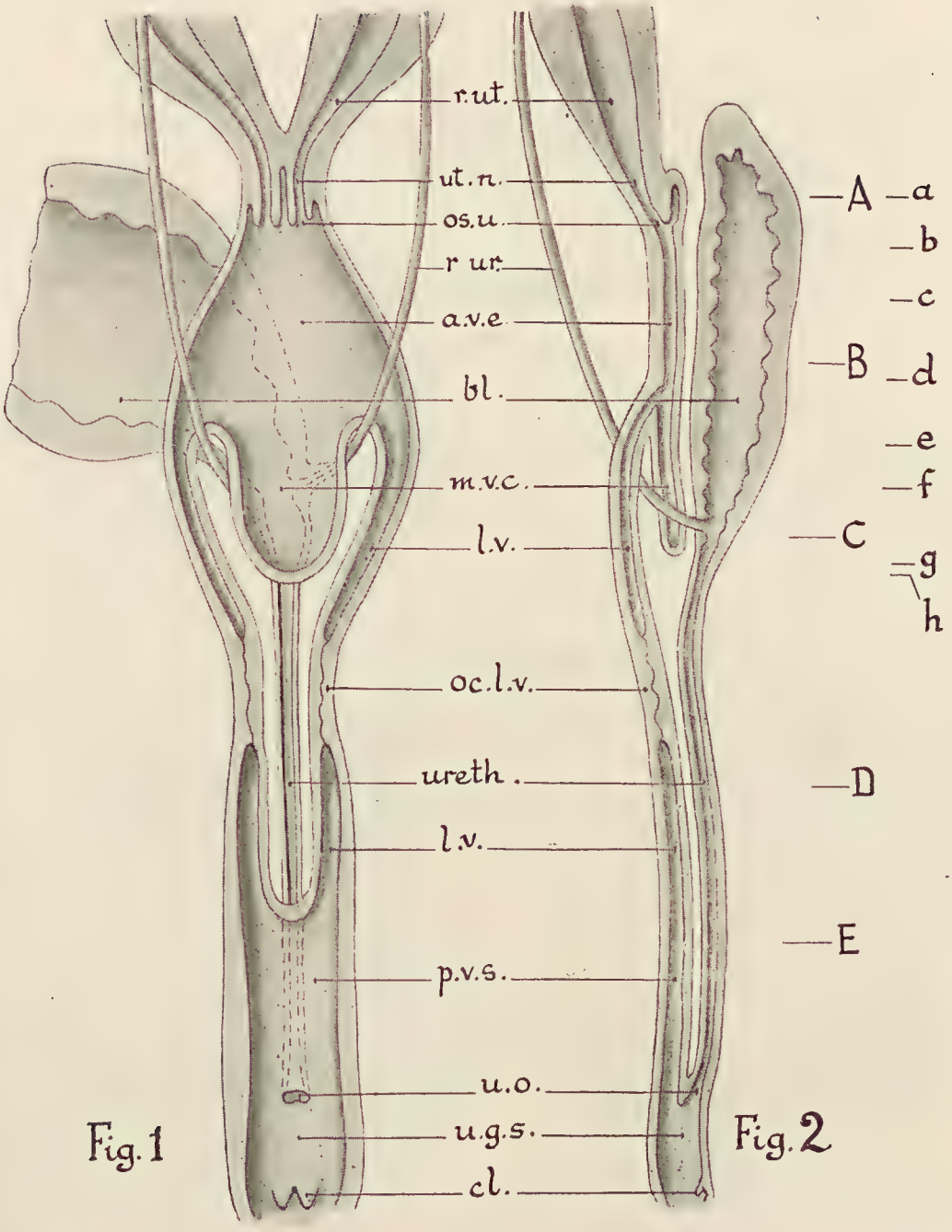

FIG. 1.—Reconstruction of the female urogenital system of *Hypsiprymnodon moschatus* (view from the dorsal surface showing a horizontal section of the various parts). x 4.

FIG. 2.—The same in sagittal section. x 4.

NOTE.—Fig. 3 shows five sections cut at the levels A, B, C, D, and E indicated above. Fig. 4 shows eight sections cut at the levels *a*, *b*, *c*, *d*, *e*, *f*, *g*, and *h* indicated above.

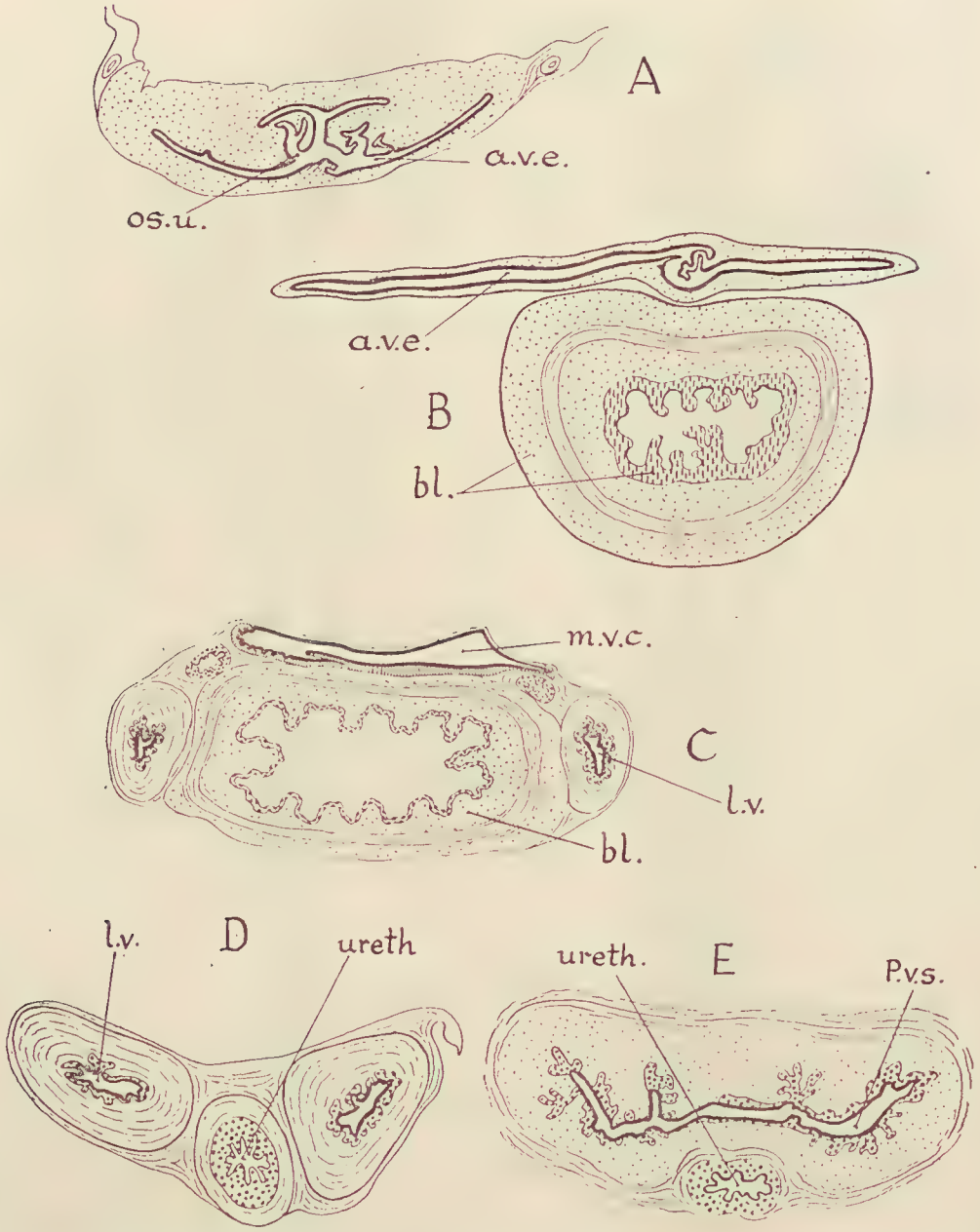

Fig. 3.—Diagrammatic drawings of transverse sections at the levels of A, B, C, D, and E respectively in figs 1 and 2.

Fig. A—t.s. through the region of the os uteri. x 15.
Fig. B—t.s. through anterior vaginal expansion. x 8.
Fig. C—t.s. at level of the cul-de-sac. x 10.
Fig. D—t.s. showing lateral vaginae and urethra. x 15.
Fig. E—t.s. through posterior vaginal sinus and urethra. x 15.

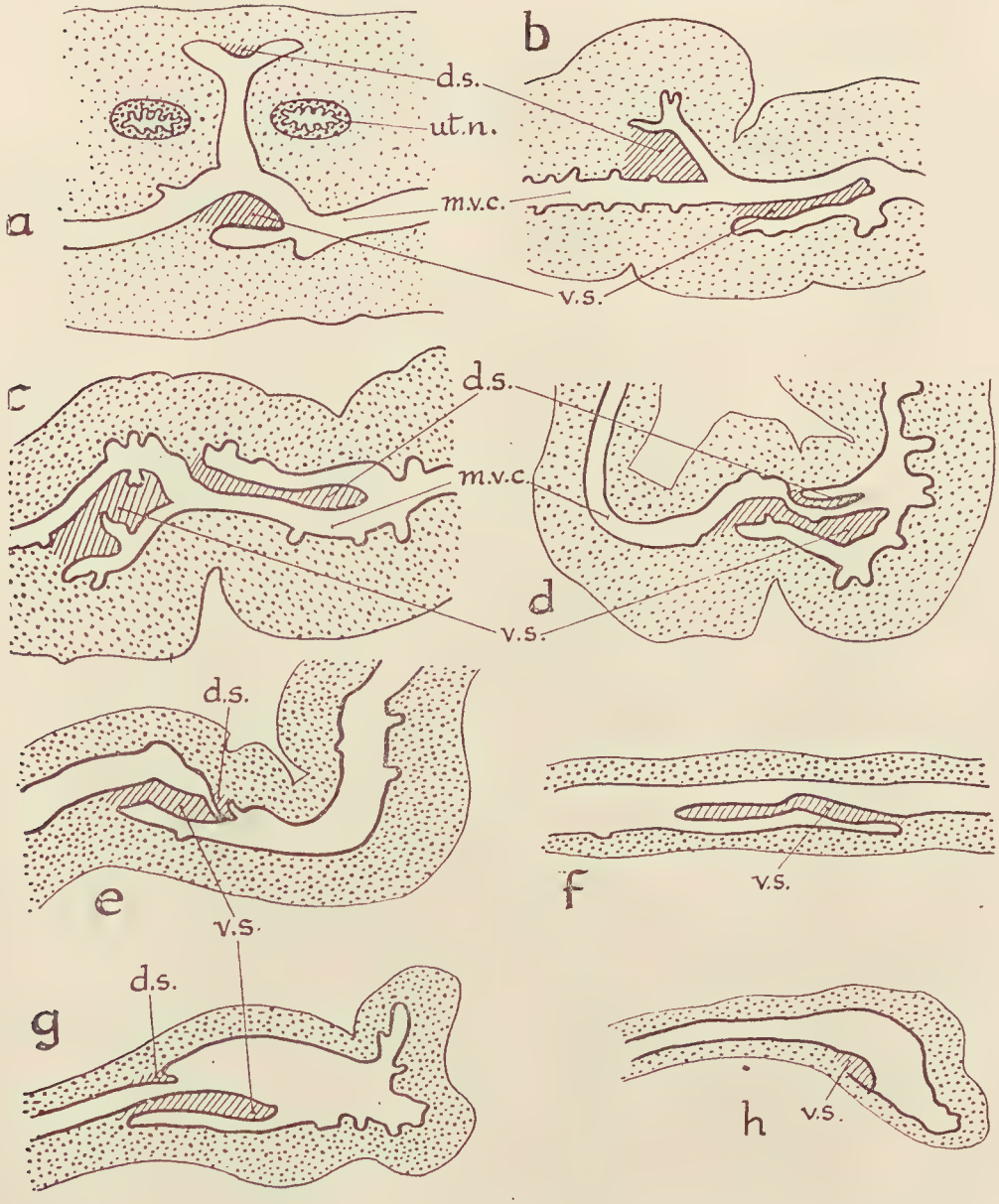

FIG. 4.—Diagrammatic drawings of transverse sections at the levels *a*, *b*, *c*, *d*, *e*, *f*, *g*, and *h* respectively in figs 1 and 2. These figures show the dorsal and ventral remnants of the septum which originally separated the right and left culs-de-sac. x 25.

NOTE.—The levels of *g* and *h* in figs 1 and 2 should be shown ¼-inch more anterior than shown at present.

Pap. & Proc. Roy. Soc. Tasmania, 1949 (15th September, 1950)

The Relationships of the Potoroidae to the Macropodidae (Marsupialia)[1]

By

Joseph Pearson
Tasmanian Museum

(Read 1st November, 1949)

With 21 Text Figures

Introduction

There is perhaps no group of mammals to which so much attention has been directed as the Marsupialia and the interests of investigators have been particularly concerned with the relationships and phylogeny of the Order. But in spite of a very considerable literature dealing with speculations on these problems we are still in doubt as to which classification would give the best picture of the phylogenetic relationships of the group. Owen's division of the marsupials into Polyprotodontia and Diprotodontia[2], though having much to commend it, is hardly more satisfactory than the division into Diadactyla and Syndactyla which was first suggested by de Blainville in 1834. Both break down hopelessly before the paradox of the Perameloidea and the enigma of the Caenolestoidea. Owing to the imperfections of the geological record the palaeontology of Australian marsupials has little to offer as a contribution to the main problems. Thus we are thrown back upon the study of the comparative anatomy and embryology of recent forms.

In the present paper we are not concerned with one of these major phylogenetic problems. The question to be discussed is whether the true kangaroos and rat-kangaroos possess sufficient fundamental characters in common to justify their being placed in the same family, as is almost universally held by systematists at the present day. This matter has already been discussed at some length (Pearson, 1946, 1947) and I then submitted new evidence to show that the rat-kangaroos (sub-families Hypsiprymnodontinae and Potoroinae) possess in common certain highly specialized structures which, in my opinion, clearly indicate close basic relationship between the two sub-families and cardinal differences from the Macropodinae. I have therefore suggested that the family Macropodidae, using the term in its older and wider sense, should be split into two families, the kangaroos (fam. Macropodidae, *s.nov.*) and the rat-kangaroos (fam. Potoroidae). A comparison of the old and new systems of classification is as follows:—

Old Classification		*New Classification*	
Family	*Sub-families*	*Families*	*Sub-families*
Macropodidae	Macropodinae Hypsiprymnodontinae Potoroinae	Macropodidae	
		Potoroidae	Hypsiprymnodontinae Potoroinae

[1] The investigations dealt with in this paper have been assisted by a grant provided equally by the Trustees of the Commonwealth Science and Industry Endowment Fund and the Tasmanian State Government.

[2] This grouping had been anticipated fifty years earlier by de Blainville in 1816.

It may be contended that the older classification satisfies all the requirements of the systematist in its insistence on the separation of the family into three groups, each of which has certain distinctive characters and that such an arrangement differs in no material way from the new classification. A further point could be made that family and sub-family rank are to some extent arbitrary terms and are often vague and unimportant. I suggest with some diffidence that many mammalogists pin their faith almost entirely upon evidence which may be obtained from skulls, dentition and external characteristics. Without wishing to detract from the value of such evidence, I feel that more use should be made of the evidence which may be obtained from the comparative study of the internal organs. Particularly in the case we are now considering, I feel that such an examination would place our knowledge of the relationships of the true kangaroos and the rat-kangraoos in an entirely different light.

There appears to be a vital principle involved in the proposed change from the old to the new system of classification. In the former we have a separation of the family Macropodidae into three sub-families. It is thereby implied that the three sub-families hold equal rank and differ from each other in certain fundamental respects, no two of them having common characteristics of outstanding importance which separate them from the third. This implication gives an entirely false impression of the set-up of the group. It will be shown later that in at least two fundamental respects in which the influence of environmental changes could not possibly have had any effect the two sub-families of rat-kangaroos agree with each other and differ jointly from the true kangaroos. I refer to the female urogenital system and the arrangement of certain bones of the temporal region of the skull. It is on this evidence that I rest my case. In the course of the present series of investigations attention has been concentrated upon the female urogenital system of the Marsupialia. A very careful and comprehensive survey of representative genera of all three Australian super-families has been made on a scale not attempted hitherto. Unique experience has been gained in the comparative anatomy of the female urogenital system of the marsupials and with this experience it is possible to say that the plan upon which this system is built in the Potoroidae constitutes an important departure from the generalized arrangement seen in nearly all marsupials, including the Macropodidae.

An attempt is made in the present paper to indicate the probable course of evolution of the families Macropodidae and Potoroidae and to show that the new classification presents a more logical and satisfactory picture of the precise relationship of one family to the other. It also provides a reasonable explanation of their line of common descent from prototypal phalangerine stock.

A system of classification is more convincing if it is based upon evidence taken from many differerent sources and particularly if due recognition is given to characters which have a high phylogenetic value. By this test the commonly accepted grouping of the true kangaroos and the rat-kangaroos into a single family lacks conviction as it is based almost entirely upon dentition and foot structure, which are highly susceptible to environmental changes.

The classic survey of the dentition and foot-structure of Australian marsupials made by Bensley (1903) did not, in my opinion, provide a satisfactory solution to the problem he set out to solve. In fact, his conclusions about the inter-relationships of the genera of the rat-kangaroos, based upon the evidence of these two characteristics were confused and contradictory (Pearson, 1946, 1947). Bensley's careful analysis made it clear that we must widen the field considerably so as to make use of characters less susceptible to changes in habitat. It is incumbent,

therefore, upon the systematist to seek more permanent and deep-seated characters which might be less susceptible to the influences of environment and which might act as valuable pointers to the phylogeny of these two families.

A careful study of the internal comparative anatomy of members of the two families has been made for the first time in the course of the present investigations. This has revealed the highly specialized nature of the female urogenital system of the rat-kangaroos and thus places the question of the relationship of the Macropodidae and the Potoroidae in an entirely new light. This ground has already been covered (Pearson, 1946, 1947) but is now presented from a somewhat different angle. Evidence will also be submitted regarding the important relationship of four bones in the temporal region of the skull, viz., the frontals, parietals, alisphenoids, and squamosals, to which attention has been directed by Finlayson (1932). No doubt, other evidence may be forthcoming in due course and it is necessary to stress once again the importance of bringing together such further evidence, particularly from those elements of the mammalian structure which are least affected by changes in external conditions of living. In my opinion, the two systems I propose to deal with come within this category.

Female Urogenital System

The comparative anatomy of the female urogenital system in the Marsupialia has been discussed at some length in previous papers (Pearson, 1945, 1946, 1947). Fig. 1 (dorsal aspect) and fig. 2 (lateral aspect) show the simplest type of adult development of the Müllerian ducts, which may be found in most members of the Didelphoidea and Dasyuroidea. Each Müllerian duct is S-shaped in both dorsal and lateral aspects.

The first arm of the S runs caudally and is composed of the Fallopian tube and the uterus. At the elbow joining the first and second arms is the vaginal cul-de-sac, which is the most proximal region of the vagina. From this arises the second arm known as the anterior vaginal canal. This passes forward and is connected with the third arm or lateral vagina which runs caudally and opens dorso-laterally into the urogenital sinus along with the lateral vagina of the other side. The urethra enters the sinus ventrally at the same level.

As a preliminary to the discussion which follows, it will be useful to enumerate the elements of the female urogenital system which, in their unspecialized condition, are to be found in the most primitive of recent marsupials. These primitive characters are:—

1. The two Müllerian ducts remain separate throughout life.
2. The two culs-de-sac are short and remain separate in the adult condition.
3. The antero-posterior length of the vaginal complex is relatively very short.
4. The vaginal complex is clearly divided into culs-de-sac, anterior vaginal canals and lateral vaginae.
5. The two lateral vaginae open into the urogenital sinus immediately after joining.
6. The urogenital sinus is relatively very long.
7. The urethra is short in relation to the total length of the urogenital system.

The Macropodidae conform to the primitive condition in the last four characters, but the Potoroidae possess none of these seven primitive characters, except that in *Hypsiprymnodon* the cul-de-sac, a single chamber formed by the fusion of the

primitive right and left culs-de-sac, is short and does not reach as far as the posterior vaginal sinus (Pearson, 1946, 1950). This character serves to strengthen the evidence in support of the view that *Hypsiprymnodon* is the most primitive member of the Potoroidae.

There are four respects in which the female urogenital system of the Potoroidae show considerable specialization. These are:—

(1) The enlargement of the anterior region of the vaginal complex to form the anterior vaginal expansion which acts as a receptaculum seminis.
(2) The fusion of the posterior parts of the two lateral vaginae to form a median dorsal tube, the posterior vaginal sinus, which opens into the urogenital sinus.
(3) The relatively small length of the urogenital sinus.
(4) The extreme anterior attachment of the urinary bladder with the consequence that the urethra is inordinately long.

In these four specialized characters the Potoroidae depart from the generalized macropod condition. An analysis of the outstanding features of the female urogenital system of the Potoroidae is given below, and differences between the two families are indicated.

1. The Anterior Vaginal Expansion (figs 4-16, *a.v.e.*)

Throughout the recent Marsupialia the lateral vaginae are not normally used for parturition but serve as ducts for the reception of the spermatozoa. These spermatazoa are usually stored in the lateral vaginae and anterior vaginal canals until their purpose has been served. In some cases, however, even in the primitive didelphoids, as pointed out by Hill and Fraser (1925) and others, the junction of each anterior vaginal canal and lateral vagina may be greatly distended by the presence of a fluid containing spermatazoa. This conversion of the anterior part of the anterior vaginal canal into a distended receptaculum seminis is also manifested in the Macropodidae. Fig. 4 illustrated the anoestrous phase in a kangaroo, a condition which differs in no fundamental respect from the phalangerid plan, and fig. 5 shows the state in the same animal in the oestrous phase when two swollen receptacula seminis are present in the anterior vaginal canals.

The condition of the anterior vaginal canals and lateral vaginae in the Macropodidae conforms to the standard marsupial pattern in which there are two receptacula seminis, right and left. The vaginal complex of the Potoroidae does not follow this pattern. Instead, the anterior vaginal region consists of a single chamber which acts as common receptaculum seminis for both sides. This

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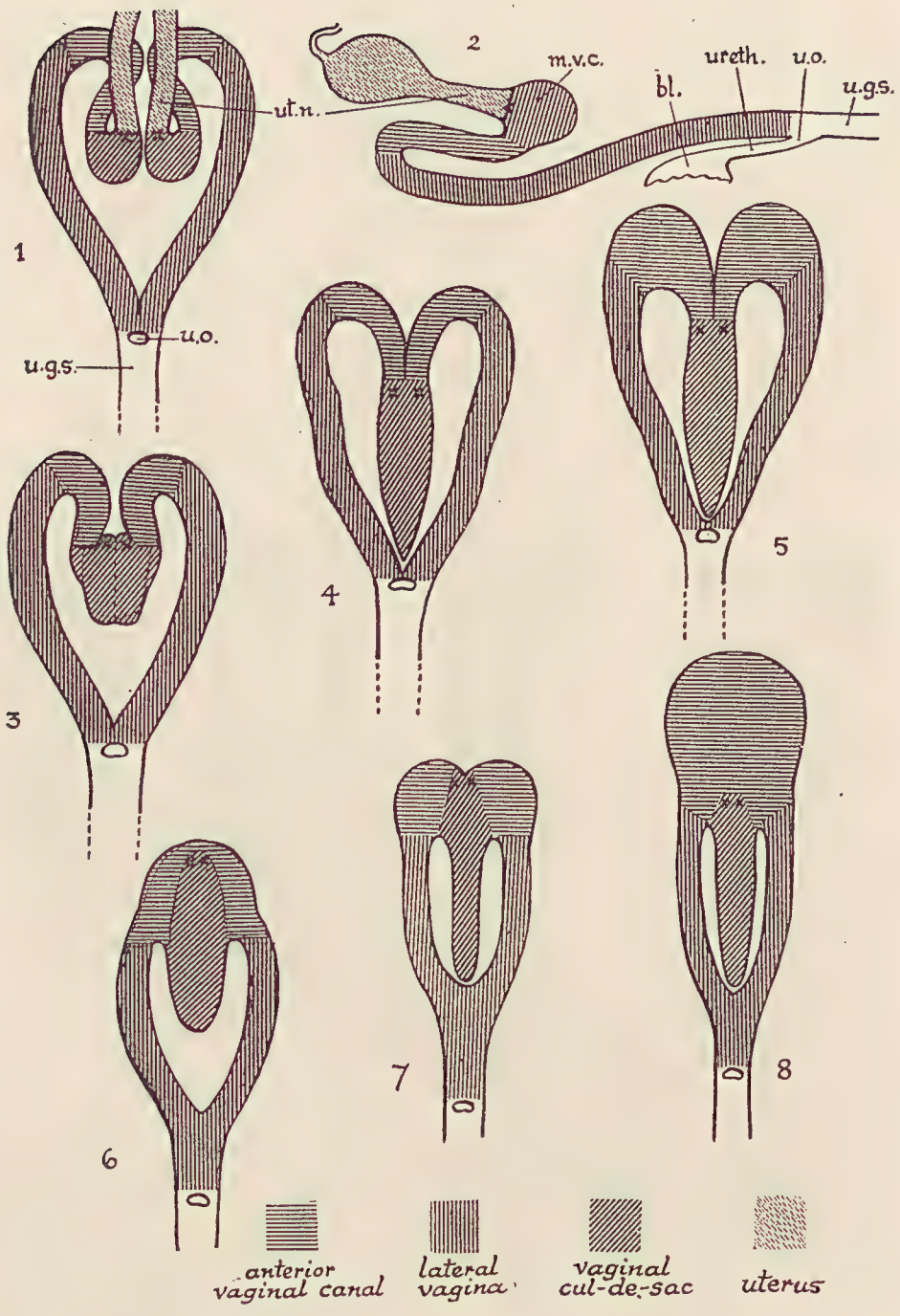
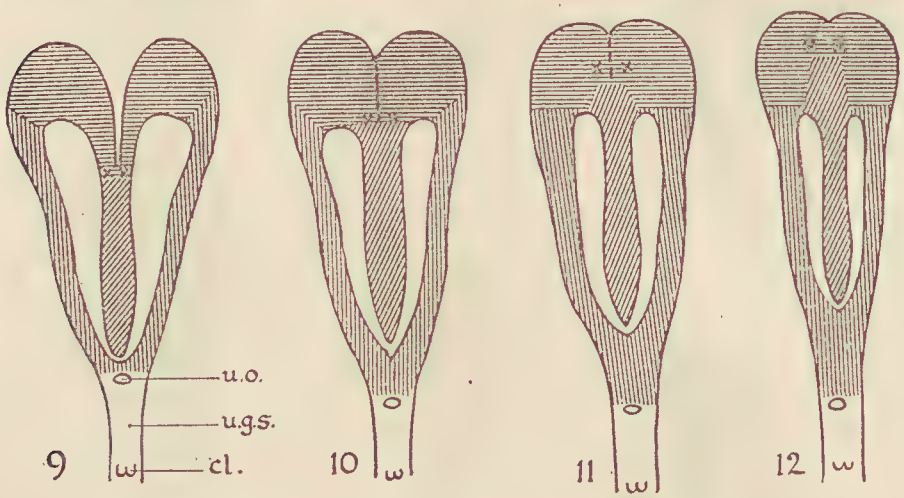
FIG. 1 (opposite page).—Condition in primitive marsupial; also early stage in marsupials generally. Dorsal view.
FIG. 2.—Same as fig. 1. Lateral view.
FIG. 3.—Condition in certain adult marsupials in which the septum between r. and l. culs-de-sac has broken down.
FIG. 4.—Condition in phalanger and kangaroo (anoestrous phase).
FIG. 5.—Condition in pro-oestrous and oestrous stages of kangaroo *(Protemnodon)* showing the swollen receptacula seminis.
FIG. 6.—*Hypsiprymnodon* showing single anterior vaginal expansion and abbreviated cul-de-sac.
FIG. 7.—*Potoroüs* showing elongated cul-de-sac.
FIG. 8.—*Bettongia* showing vaginal caecum (modified anterior vaginal expansion).
NOTE.—The position of each os uteri is represented by a small cross.



Diagrammatic comparison of the vaginal system of various marsupials (see footnote on opposite page).

is a distinct advance on the macropod condition and is found nowhere else in the Marsupialia. This chamber, which is known as the anterior vaginal expansion (Pearson, 1945), occupies the whole of the anterior portion of the vaginal complex of the Potoroidae and is a characteristic feature of the family. All genera of the family*, including the more primitive *Hypsiprymnodon*, have this character in common and differ in this respect from the Macropodidae. In my original description of the anterior vaginal expansion I defined it as an extension of the anterior portion of the vaginal culs-de-sac and the lateral vaginae. In defining it thus, I had in mind that each lateral vagina, consisting of a proximal and distal loop, might be regarded as that part of the vaginal complex which linked the cul-de-sac with the urogenital sinus. Perhaps, however, it would be more correct to recognize Hill's definition of the proximal limb as the anterior vaginal canal (Hill, 1899), so that the anterior vaginal expansion may more strictly be regarded as the homologue of the right and left anterior vaginal canals together with the anterior portion of the cul-de-sac. The precise difference between the receptacula seminis in the Macropodidae and the receptaculum seminis (anterior vaginal expansion) in the Potoroidae can best be understood by referring to figs 5 and 7 which represent the oestrous stage of the Macropodidae and the normal condition found in *Potorous* respectively.



Transition from vaginal condition in Macropodidae to that in Potoroidae.

FIG. 9.—Oestrous condition in kangaroo *(Protemnodon)*.
FIGS 10, 11.—Hypothetical intermediate stages linking figs 9 and 12.
FIG. 12.—Potoroüs.

Figs 9-12 show how the Macropod condition of the anterior vaginal canals (figs 5 and 9) may have become converted into the typical Potoroid condition in which the right and left anterior vaginal canals have coalesced to form a single chamber, the anterior vaginal expansion (figs 7 and 12). Figs 10 and 11 are hypothetical intermediate stages in this sequence. Further complications are seen when we pass from the simple condition seen in *Hypsiprymnodon* (fig. 6) and *Potoroüs* (figs 7 and 12) to a more complicated arrangement in *Caloprymnus*

* The condition in *Aepyprymnus* is at present unknown though it can be forecast with certainty that its urogenital system will agree substantially with the condition found in other members of the family.

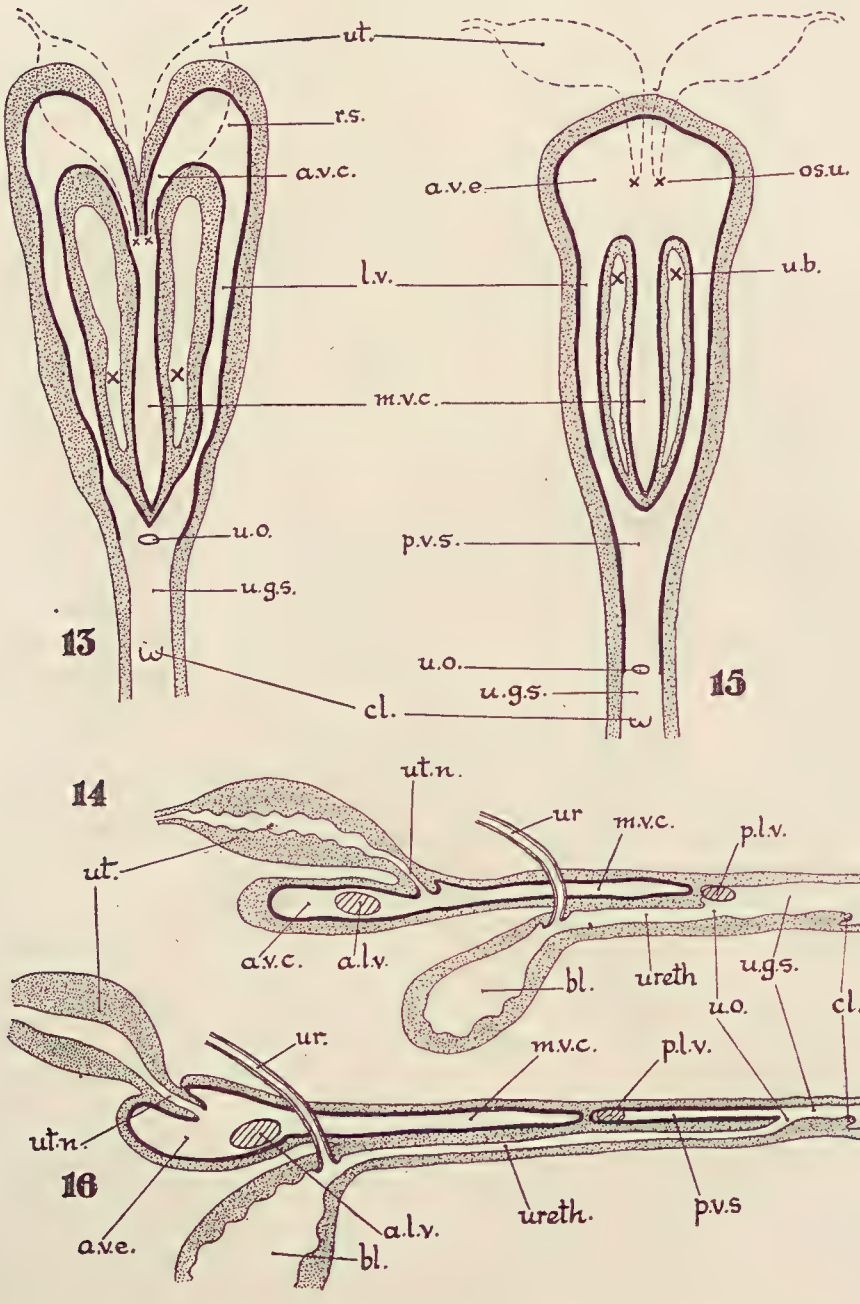
in which the right and left portions of the chamber are expanded into wings (Pearson, 1946, p. 15). From this condition it is not difficult to conceive how the most specialized arrangement, seen in *Bettongia*, is reached (fig. 8). Here we have a large vaginal caecum which is homologous in every respect with the anterior vaginal expansion. It is interesting to note in passing that a specialization similar to that of *Bettongia* is also found in the perameloids where, however, a septum is present completely separating the right and left halves of the vaginal caecum.*

If we refer for a moment to the phylogenetic tree given in fig. 21 it may be stated without question that throughout the macropod line of evolution represented by stems A, D, E, and F the general plan of the vaginal complex conforms to the typical marsupial condition found in the prototypal phalangerines. The diversion at E leads to the Potoroidae and, presumably, it was somewhere along stem E that the right and left anterior vaginal canals became merged into a single chamber which we know as the anterior vaginal expansion.

2. Median Vaginal Cul-de-sac (figs 13-16, *m.v.c.*)

As we have seen *Hypsiprymnodon* is the only living representative of the two families we are now discussing in which the fused right and left culs-de-sac remain in the primitive abbreviated condition in parous adults. It may be taken for granted, therefore, that the primitive stock from which all rat-kangaroos have been derived (stem G, fig. 21) was characterized by the possession of a short cul-de-sac which may have retained the primitive double condition in parous adults. It would follow, too, that stem D had this primitive characteristic. A good deal has been written (Brass, 1880, Lister and Fletcher, 1881, and others) about the advanced development of the cul-de-sac in some of the recent Macropodidae which is said to culminate in the establishment of a permanent connexion between the cul-de-sac and the urogenital sinus to form a 'median vagina' after the first parturition in some species. Brass (1880) went so far as to state that in Bennett's Wallaby a permanent median vagina was produced in non-parous specimens. All these earlier observations were based upon ordinary dissections. In an earlier paper (Pearson, 1945) I was prepared to accept without question the conclusions of these pioneer workers. In the course of the present investigations, however, detailed examinations of serial sections have proved that in some cases at least non-parous specimens of Bennett's Wallaby do not possess a connexion between the cul-de-sac and urogenital sinus. It would, I think, be a fairer statement of the case to say that a permanent median vagina lined with continuous epithelium may be present in some individuals of a species and not in others. Beyond such a general statement it would be dangerous to go, but further evidence is being collected on this question. The above statement need not affect, however, the general discussion and conclusions on this point already given in earlier papers (Pearson, 1945, 1947). In the matter of parturition, it is clear that the Potoroidae have not developed a permanent median vagina and the inadequate evidence available shows that, in some cases at any rate, parturition takes place through the lateral vaginae (Pearson, 1945, p. 83). The only two recorded instances of observed parturition in the Potoroidae were through the lateral vagina, so that I ventured to state that it was *probable* that this type of parturition was characteristic of the family. Professor J. P. Hill *(in litt.)* did not agree with this conclusion. As my opinion was qualified, I am prepared to abide by it pending further evidence.

* The right and left Müllerian ducts do not, however, remain completely separate in the Perameloidea as the septum between the right and left culs-de-sac breaks down in parous specimens.



Comparison of urogenital system in the Macropodidae and Potoroidae (see footnote on opposite page).

The vaginal complex of the Macropodidae (figs 4, 5, 9, and 13) is so constructed as to offer two alternative paths for parturition after the foetus leaves the os uteri, first, to continue in a direct line in a caudal direction through the cul-de-sac and thus take the line of least resistance. The alternative route to reach the urogenital sinus would be to double back along the hair-pin bend of the anterior vaginal canal and lateral vagina, a devious path which would offer insuperable difficulties. This double vaginal kink is characteristic of most marsupials, including the more primitive groups (Hill, 1899, &c.), and has resulted in pseudovaginal parturition in a caudal direction along the median line. In the case of the potoroids, however, the formation of the anterior vaginal expansion has caused its connexion with each lateral vagina to be placed in the posterior wall of the sinus (figs 6 and 7) caudal to the ora uterorum. In such cases the foetus after emerging from the os uteri has three courses open to it, along the cul-de-sac or along the lateral vaginae. The median path is not much more accessible than the lateral paths and parturition by the lateral vaginae in the Potoroidae may be common if not almost universal. The prototypal marsupials probably used the lateral vaginae for parturition, but this habit in the Potoroidae is not primitive but is a secondary return to the primitive and is therefore specialized.

It follows that the type of parturition established in the Macropodidae is a direct development of the pseudovaginal parturition which is found in all recent marsupials. The only method of parturition so far observed in the Potoroidae is a secondary return to the prototypal marsupial condition brought about by the specialization of the anterior part of the vaginal complex.

3. The Posterior Vaginal Sinus (figs 15, 16, *p.v.s.*)

The urogenital sinus, as its name denotes, is formed by the confluence of the posterior extremities of the lateral vaginae on the dorso-lateral side, and the urethra on the ventral side. Before entering the sinus the lateral vaginae fuse to form a common chamber, the posterior vaginal sinus, which is of infinitesimal length in most marsupials including the Macropodidae. The Potoroidae, however, are exceptional in this respect as the posterior vaginal sinus is of considerable size. This common vaginal tube runs dorsal to the urethra for a considerable distance before emptying into the urogenital sinus. In this respect the Potoroidae are widely different from all other marsupials, including the members of the Macropodidae. This is obviously a specialization and in this respect the Macropodidae are simpler and more generalized than the Potoroidae. It is suggested that the posterior vaginal sinus is formed by the fusion of the embryonic sinus horns of the right and left sides, though material to prove this point has not yet been obtained.

4. The Urogenital Sinus (figs 13-16, *u.g.s.*)

In the Didelphoidea, the Dasyuroidea, the Caenolestoidea, and the Phalangeroidea, with the exception of the Potoroidae, the urogenital sinus is of considerable length and this may justly be regarded as the primitive condition. In all members of the Potoroidae the urogenital sinus is extremely short, a condition which is not primitive.

Fig. 13 (opposite page).—Urogenital system in Macropodidae. Dorsal view. (Two small crosses represent position of each os uteri. Two larger crosses represent position of connexion of ureters with neck of bladder.) (This applies to figs 13 and 15.)

Fig. 14.—Urogenital system in Macropodidae. Lateral view.

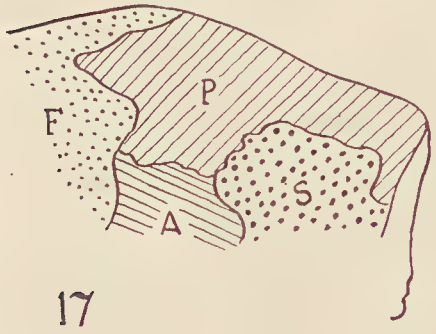
Fig. 15.—Urogenital system of *Potoroïs*. Dorsal view.

Fig. 16.—Urogenital system of *Potoroïs*. Lateral view.

5. The Attachment of the Urinary Bladder (figs 14, 16)

Both the Perameloidea and the Potoroidae differ in a marked manner from all other marsupials in the extreme forward position of the attachment of the urinary bladder. As a consequence, the urethra is inordinately long in relation to the size of the other parts of the female urogenital system. By comparison the urethra of the Macropodidae is short and the attachment of the bladder conforms to the arrangement found in the remaining marsupial groups. The extreme anterior attachment of the bladder in the Potoroidae (fig. 16) marks this family as having departed from the normal and more primitive condition found in the Macropodidae (fig. 14) and the rest of the Phalangeroidea.

To sum up, a survey of these main features of the urogenital system makes it evident that this system in the Potoroidae is highly specialized and can readily be distinguished from that of the Macropodidae. Also it seems clear that in the course of evolution the general set-up of the female urogenital system of the Potoroidae has departed considerably from the generalized marsupial condition which the members of the Macropodidae share with most of the major groups of the Marsupialia.



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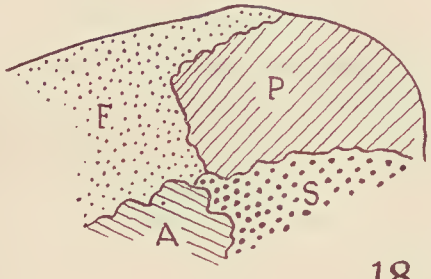

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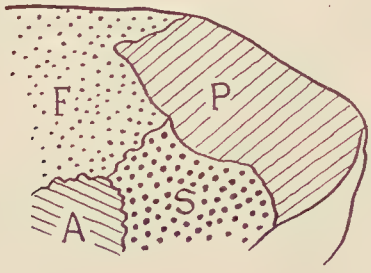

19

Arrangement of the temporal bones throughout the Marsupialia.

Fig. 17.—Condition in the super-families Didelphoidea, Dasyuroidea (except *Thylacinus*). Caenolestoidea and Phalangeroidea (except Potoroidae).

Fig. 18.—Condition in *Hypsiprymnodon* (Potoroidae).

Fig. 19.—Condition in Potoroidae (except *Hypsiprymnodon*), *Thylacinus* (Dasyuroidea), and the super-family Perameloidea.

The Temporal Bones (figs. 17-20)

As already indicated, certain bones of the temporal region of the skull provide an interesting contribution to our problem. These bones are the frontals, parietals, alisphenoids, and squamosals. In all marsupials, with the exception of the super-family Perameloidea, the family Potoroidae, and the genus *Thylacinus*, the parietal at each side of the skull makes a wide contact with the alisphenoid thus separating the frontal from the squamosal (fig. 17). This is the condition found in the Macropodidae, so that this family follows the normal and presumably archaic marsupial pattern in this respect. On the other hand, the members of the Potoroidae show the reverse condition, that is to say, the frontal and squamosal meet over a relatively wide front with the consequent wide separation of the parietal and alisphenoid (see fig. 19). At first sight it is difficult to explain how such a complete reversal of bone arrangement and relationship could have been brought about, and the evidence of *Hypsiprymnodon* is important in this connexion. In this genus it is found that the relationship of these bones follows the potoroid pattern with this important qualification, that the junction of frontal with squamosal is a very narrow one so that the parietal and alisphenoid almost meet (fig. 18). Thus the condition in *Hypsiprymnodon* represents a transition from one extreme phase to the other and shows how the change has been brought about (see fig. 20, *(a)-(e)*).

Fig. 20 shows five stages in the transition from one extreme condition to the other. Fig. 20 *(a)* is the condition in the typical marsupial including the Macropodidae. Fig. 20 *(b)* is merely a variant of *(a)*. Fig. 20 *(c)* is a hypothetical stage in which all four bones meet. Fig. 20 *(d)* is the *Hypsiprymnodon* plan, and finally fig. 20 *(e)* shows the condition in the more highly specialized members of the Potoroidae.

It is clear from the above description that the arrangement of the four bones in the Potoroidae is a departure from the primitive condition found in most marsupials including the Macropodidae. The condition in *Hypsiprymnodon* approaches more closely to the primitive condition than the other genera of the Potoroidae, but is definitely of the potoroid type. We may conclude, therefore, that with regard to the temporal bones, the Potoroidae depart considerably from the normal marsupial condition found in the Macropodidae. A reference to fig. 21 will, perhaps, make this clear. The main phalangerine-macropod stem (A, D, E, and F) carries the bone-relation shown in fig. 17. Stem G, which represents the point of divergence of the Potoroidae from the main stem, would contain species, all now extinct, which probably showed the condition seen in fig. 20 *(b)* (in the most ancient forms), and the condition in fig. 20 *(c)* in still later but now extinct forms, and finally at the point where H and J fork, a condition somewhat similar to the *Hypsiprymnodon* condition (fig. 20 *(d)*).

Phylogenetic Considerations

I have already expressed the view (Pearson, 1947) that both the kangaroos and rat-kangaroos 'may have arisen from the same primitive phalangerine stock, but in the course of subsequent evolution have both become specialized in different ways', that is to say, they are collateral groups derived from a common ancestor. Tate (1948) has interpreted my views to mean 'that the Macropodidae comprise two families derived independently from the phalangeroid stock'. This interpretation which might suggest that the two groups deviated from the main line at two different levels would not accord with my views. I conceive both families (fig. 21, E and G) as having sprung from a common stock (fig. 21, D) which itself

had branched from the main phalangerine stem (fig. 21, A) at an earlier stage. This was demonstrated in a previous paper (Pearson, 1947, fig. 2). Any basic characters which the Macropodidae and Potoroidae may have in common could be explained, therefore, on the ground that they were collaterals having a considerable degree of common heritage. Any resemblances which the two families may possess, such as certain features of dentition and foot structure may be due to nothing more than the circumstance that these two collateral families, derived from the same common stock, are living for the most part under somewhat similar conditions. That is to say, these resemblances may be the outward and visible sign of the effects of a common environment upon the gene complexes of two closely related families which have many genes in common.

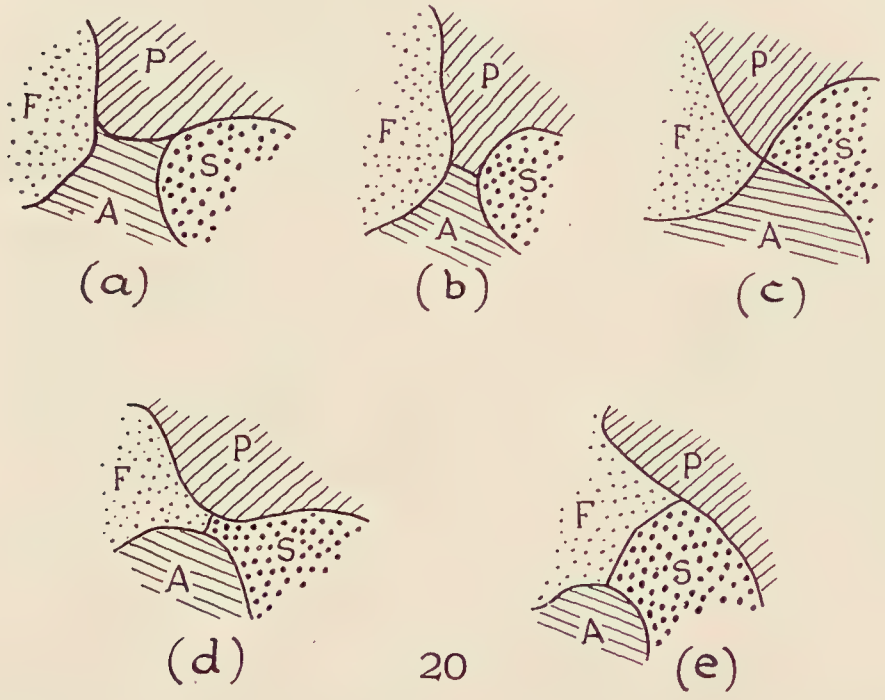

FIG. 20.—Diagrammatic representation of the arrangement of the temporal bones in the Marsupialia.
a—Typical marsupial condition (except Peramaloidea, Potoroidae, and *Thylacinus*).
b—A varient of fig. *a*.
c—A hypothetical stage when all four temporal bones meet.
d—*Hypsiprymnodon*.
e—Condition in Perameloidea, Potoroidae (except *Hypsiprymodon*), and *Thylacinus*.

Tate (1948) saw difficulties in the proposed establishment of a separate family for the rat-kangaroos. He considered that it would involve not only the invocation of convergence to explain similarities in structure of the hind limbs of both families, but also the further admission of a 'very complex' convergence to account for the similarity between the third and fourth premolars in both families as well as the replacement of the third premolar and milk fourth premolar by the permanent fourth premolar. He regarded these two sets of 'unrelated examples

of morphological identity—foot structure and premolar structure' as pointing much more strongly to real relationship than to convergence, a relationship which justified the widely accepted view that both groups should be placed in the same family.

Convergence, which implies a similarity of structure acquired by two or more unrelated forms, need hardly be invoked in support of my case, as I too, in company with Dr. Tate, admit the basic relationship of the two families, as may be seen from fig. 21. Certain similarities in dentition and foot structure in the two families are not due to convergence but rather to inheritance from common ancestors (stem D) and any differences there may be are due to *divergences*. Divergence has produced the differences; heredity has accounted for the resemblances. In particular, there is the major divergence of the basal potoroid stock (stem G) from the phalangerid-macropod line involving important specializations of the female urogenital system and new arrangement of some of the temporal bones. Thus the two families possess homologous features in dentition and foot structure and also important morphological divergences.

Analysis of Fig. 21

My conception of the phylogenetic relationships of the Macropodidae and the Potoroidae are explained diagrammatically in fig. 21. A close examination of this phylogenetic tree is necessary in order to follow my views on this question. These are set out below.

Stem A

Stem A represents the ancestral phalangerine stock from which all members of the super-family Phalangeroidea may be assumed to have arisen. Its members possessed a generalized diprododont dentition suited to an omnivorous diet. In conformity with such a diet they possessed a simple stomach and a small caecum. Such arboreal animals had a syndactylous pes with a functionally apposable hallux. The fourth toe was only slightly longer than the other toes.

In the skull the alisphenoid was in contact with the parietal over a broad front, thus widely separating the frontal from the squamosal. The female urogenital system was built on the same generalized pattern found to-day in the primitive Didelphoidea. That is to say, there was a short cul-de-sac on each side, and the extreme antero-posterior length of the vaginal complex was shorter than the urogenital sinus. In all probability, at this phylogenetic stage the right and left Müllerian ducts were still completely separated throughout life.

Stem A is represented as having divided into two important branches, stem B which give rise to the recent families Phalangeridae and Vombatidae with which we are not concerned in the present discussion, and the other, stem D, from which arose the common ancestors of the Macropodidae and the Potoroidae.

Stem D

Stem D was probably evolved in response to changes in climatic conditions which resulted in the gradual replacement of rain forests by low scrub and sparsely timbered country which later in their turn gave place to grass plains. This gradual change in habitat would be accompanied by certain structural modifications in the hind limbs involving gradual hypertrophy of the hind limbs in general and the enlargement of the fourth toe and the consequent reduction of the fused second and third digits of the foot and the ultimate loss of the hallux. It should be noted, however, that at this stage the hypertrophy of the hind limbs and the lengthening of the fourth digit of the pes could not have proceeded very far and a functional apposable hallux was undoubtedly still present.

This gradual change in foot structure was probably accompanied by a transition from the type of omnivorous diet common to most small arboreal mammals living in the rain forests to the more strictly herbivorous diet usual in the denizens of low scrub and thickets on the edge of the open plains. This, again, changed to the more specialized grazing habits of the inhabitants of the grass plains living under more arid conditions. Such changes in habitat and habit would be reflected in dental adaptations and in the consequent specializations of the alimentary canal which were called forth in response to new conditions.

According to Abbie (1939) the changed diet of the Macropodidae and the Potoroidae results in the greater development of the masseter muscle. Hence the presence of a well-developed masseteric fossa and masseteric canal in these families. The masseteric canal is not present in the phalangerines and hence it must have made its first appearance in stem D.

However, these specializations in dentition and in other respects which ultimately were to produce the Macropodidae and Potoroidae were not fully developed at this stage, but stem D marked a definite departure from the phalangerine condition. This departure which was probably governed to a certain degree by the gradual change in habitat conditions already referred to resulted in the development of characteristics which in the aggregate ultimately produced the immediate ancestors of the Macropodidae and Potoroidae, which differed from the prototypal phalangerine stock in a number of respects, including the following:—

1. The third premolars gradually became restricted to immature individuals and were morphologically very similar to the permanent fourth premolars.
2. The deciduous fourth premolars became molarized in shape so as to be scarcely distinguishable from the true molars. The permanent fourth premolars gradually increased in size.
3. In nearly all cases the permanent fourth premolar replaced the third premolar and the deciduous fourth premolar.
4. The masseteric canal gradually developed in the mandible.
5. The gradual hypertrophy of the hind limbs and other changes in the pes, such as the dominance of the fourth digit, the loss of the hallux, and the reduction of the second and third digits.

With the exception of these five characters, stem D probably differed little from stem A, that is to say, the female urogenital system retained the generalized phalangerine condition, the arrangement of the temporal bones was unaltered, the alimentary canal possessed a simple stomach and small caecum, the hind limbs perhaps showed slightly greater development, and the fourth digit of the pes showed the beginning of the elongation which ultimately became a feature in most of the descendants of this stem.

It is of interest to note that the change from the omnivorous diet of the prototypal phalangerines to the more strictly herbivorous (arboreal) diet of the recent phalangers, on the one hand, and the herbivorous (grazing) diet of the kangaroos, on the other, has been accompanied by certain modifications of the stomach and caecum which have their counterpart in the eutherian mammals. As we have seen, the primitive phalangers which were omnivorous had a simple stomach and a short caecum. In the recent phalangers which are herbivorous the stomach is still simple but the caecum is long, varying in length from 14 per cent to 20 per cent of the total length of the intestine. In the Macropodidae and

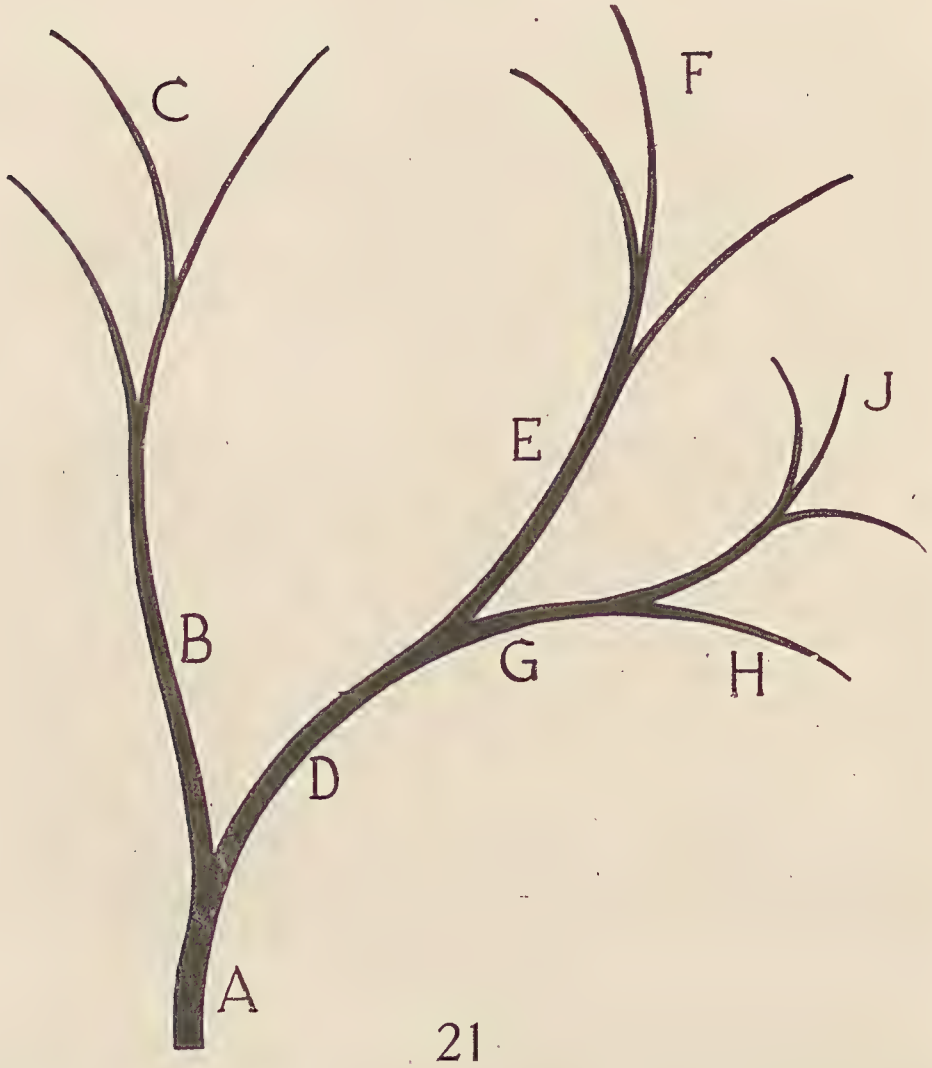

FIG. 21.—Phylogenetic Tree of the super-family Phalangeroidea, particularly to show the relationship between the Macropodidae and the Potoroidae.

A—Primitive phalangeroid stock.

B—Ancestral stem from which families Phalangeridae and Vombatidae arose.

C—Recent Phalangeridae and Vombatidae.

D—Divergence from the main phalangeroid stem, representing the common ancestors of the kangaroo group (Macropodidae and Potoroidae).

E—Ancestral stem from which recent members of family Macropodidae have arisen.

F—Recent Macropodidae.

G—Divergence from the phalangeroid-macropod line, representing the stem from which recent members of family Potoroidae have arisen.

H—Sub-family Hypsiprymnodontinae.

J—Sub-family Potorinae.

Potoroidae, with the exception of *Hypsiprymnodon*, the stomach is complicated and the caecum is short varying in length from 1·8 per cent to 4·2 per cent of the total length of the intestine.

Stem D branched in two directions, stem E representing the continuation of the main phalanger-macropod line from which recent Macropodidae (F) have been derived; and G which was the basal stem from which recent Potoroidae have sprung. The phalangerine-macropod line passed through A, D, E, and F, and in this series a gradual change took place from an arboreal animal with an omnivorous diet to ground-living forms with cursorial and in the most extreme development, a saltatorial type of locomotion. These changes were accompanied by changes in morphology of the hind limbs which culminated in the highly specialized hind limbs and feet of the kangaroos. At the same time, these more specialized forms acquired the true grazing habit which was reflected in the special type of dentition of the true kangaroos.

Stem E

Stem E represents the ancestral Macropodidae, and on the whole it followed the ancestral phalangerine plan (stem A) with certain modifications, which we have already seen in stem D. In fact, the main features of stem E were already present in stem D and differed only from the latter in degree of specialization. For example, the pes became more elongated with special emphasis on the fourth digit. The hallux probably became greatly reduced and finally disapeared. The temporal bones remained as in stems A and D. The simple stomach gradually assumed complications and the caecum became still more reduced in size. The female urogenital system retained the general phalangerine plan and the dentition became more suited to the grazing habit. The fourth premolars were relatively insignificant and during the growth of the skull were gradually pushed forward to make way for the developing molars. Accompanying this gradual change in habitat along the Phalangerid-Macropod line certain morphological changes took place. In the main, however, the phalangerine characteristics persisted, modified, of course, by superficial influences which gradually affected foot structure, dentition, and the alimentary canal. However, the more deep-seated characters, such as those associated with the female urogenital system and the disposition of the temporal bones, did not change materially from the typical phalangerine arrangements.

Stem G

Stem G may be regarded as the ancestral line from which the recent Potoridae (sub-families Potoroinae and Hypsiprymnodontinae) have been derived. Raven and Gregory (1946) have dealt with the question of the 'adaptive branching of kangaroos', as they termed it, in an interesting manner. There is no question that the influences of habitat have wrought certain clear-cut changes in such characteristics as foot-structure and dentition, but it may be questioned whether the results produced by a study of the effects of environment are in themselves sufficient to justify the conclusions to which systematists have come. If by 'adaptive branching' Raven and Gregory mean nothing more than the response of structure to habit and habitat, then I am willing to fall into line. If, however, the diagram which serves to illustrate their thesis represents a phylogenetic tree of the true kangaroos and rat-kangaroos, it would appear that due consideration has not been given to structures which are least affected by environmental changes. Hence my conception of the phylogeny of these groups given in fig. 21 differs fundamentally from theirs. Stem G is vital in this connexion, as it is at this

point that the Potoroidae departed from the phalangerine-macropod line to develop certain morphological characteristics which clearly separate them from the ancestral phalangerine stock and also from the Macropodidae.

If, for example, the rat-kangaroos, including *Hypsiprymnodon*, differed from the true kangaroos only in such external features as dentition and foot-structure, it would be justifiable to regard all forms which were derived from this stem as being sufficiently homogeneous to justify their being placed in a single family. However, it has been shown in the present paper that the Hypsiprymndontinae and the Potoroinae are united by two fundamental characteristics, the specializations of the female urogenital system in which they differ from all other marsupials including the Macropodidae, and the arrangement of the temporal bones in which they differ from the Macropodidae and all other marsupials with the exception of the Perameloidea. These two fundamental departures from the normal marsupial plan must have taken place *after* stem G had been established since it has been shown that all recent derivatives from stem G, the Hypsiprymnodontinae and the Potorinae alone possess this unique combination of attributes and in this respect differ from all other members of the Phalangeroidea. Moreover, these two departures can hardly be regarded as adaptations 'in relation to habitat'.

Stem G probably had the following characteristics, many of which differed but little from those of stem D:—The hind legs were relatively short and the predominance of the fourth digit of the pes was not pronounced. The pes had a well-developed hallux which may still have been functionally apposable. Digital pads were present, the teeth were characterized by the dominance of the posterior premolars and the relatively small size of the molars. The third premolar was probably unlike the fourth premolar. The stomach was simple and the caecum was small. The present specializations of the urogenital system had already begun to take shape and the arrangement of the four temporal bones was such that all four probably met (see fig. 20 *(c)*).

Stems H and J

Stems H and J represent recent Hypsiprymnodontinae and Potorinae respectively. They both agree in having the specialized type of urogenital system, and the disposition of the four temporal bones in which the frontals and squamosals meet. An analysis of foot structure and dentition does not help much in determining the precise relationships of the various genera within the group.

Raven and Gregory talk about the heritage which *Potoroïs* derived from *Hypsiprymnodon* and that '*Bettongia* inherits from *Hypsiprymnodon* . . . most features of its dentition'. I think a much clearer picture would be obtained if we came to the logical conclusion that all recent rat-kangaroos, including *Hypsiprymnodon*, represent the more recent branches of a complicated tree. My view is that the relatively primitive *Hypsiprymnodon* and the more specialized remaining genera of the family have all been derived from a common stock (stem G), and the fact that *Hypsiprymnodon* is more primitive than the other genera of the Potoroidae does not mean that the more specialized genera have 'inherited' certain characteristics from *Hypsiprymnodon*, but from the common stock (stem G) from which all these genera have sprung.

Summary

The object of the present paper is to examine the relationship of the Macropodidae and the Potoroidae. Previous investigators have depended almost entirely upon dentition and foot structure and have, in my opinion, failed to provide an acceptable solution. Bensley (1903) was vague in his conclusions on this question,

but he regarded the Potoroidae as being more primitive than the Macropodidae and thought it possible that the Macropodidae arose from the *Potorous-Caloprymnus* stock, or that both groups arose from a primitive *Dromicia*-like phalanger. In my opinion the first alternative is improbable and the second is more likely to be nearer the truth. Raven and Gregory (1946) agreed with earlier writers who considered *Hypsiprymnodon* to be the only remaining representative of the ancestral stock from which both the rat-kangaroos and true kangaroos have been derived. The evidence given in the present paper claims that this view is quite untenable. It has been shown that the Macropodidae follow the primitive phalangerine plan as regards the female urogenital system and the arrangement of the four temporal bones. On the other hand, *Hypsiprymnodon* and the other genera of the Potoroidae have departed considerably from this plan and it is inconceivable that the rat-kangaroos, which are specialized in these two important respects, could have given rise to the kangaroos. I regard these two groups of structures as being insulated from the effects of habitat, and are thus more static, whereas foot-structure and dentition are unreliable and contradictory witnesses, since they are plastic and responsive to the influences of a changing environment. Gregory (1910) stressed the value of brain, skull, and urogenital system as phylogenetic criteria and issued a timely warning against attaching too much importance to the evidence of the teeth and foot structure.

The resemblances in foot structure and dentition which link the Macropodidae and Potoroidae need not be ascribed to convergence, since the burden of the present claim is that the two families are collateral offshoots from a common ancestral stock. Such resemblances are due to homology and not homoplasy. It is equally true that any changes which took place in the arrangement of the female urogenital organs and in the disposition of the temporal bones along stem G, resulting in considerable specialization, may be regarded as outstanding examples of divergence.

The present series of investigations has been in progress for several years. The ulterior object is to clear up some of the phylogenetic problems of the Marsupialia. In the present paper it is insisted that the evidence shows that the specialized female urogenital system of the Potoroidae has departed from the archaic marsupial plan and differs from the Macropodidae in this respect. It is considered incompatible with the evidence that the Macropodidae should be regarded as an offshoot from a primitive *Hypsiprymnodon*-like rat-kangaroo. Rather is it considered that the two families are collateral branches of a common stock derived from primitive phalangers. The Potoroidae are a specialized offshoot from the phalangerine-macropod line and it is claimed that the evidence of the female urogenital system and the arrangement of the temporal bones lend support to this conclusion and justify the establishment of the family Potoroidae.

References to Figures

A—alisphenoid
a.l.v.—anterior extremity of lateral vagina
a.v.c.—anterior vaginal canal
a.v.e.—anterior vaginal expansion
bl.—bladder
cl.—clitoris
d.s.—dorsal remnant of septum
F—frontal
l.ut.—left uterus
l.v.—lateral vagina
m.v.c—median vaginal cul-de-sac
os u.—os uteri
P—parietal
p.l.v.—posterior extremity of lateral vagina
p.v.s.—posterior vaginal sinus
r.s.—receptaculum seminis
S—squamosal
u.b.—opening of ureter into the bladder
u.g.s.—urogenital sinus
u.o.—opening of urethra into urogenital sinus
ur.—ureter
ureth.—urethra
ut.n.—uterine neck
v.s.—ventral remnant of septum

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Preliminary Account of the Palaeontology and Palaeoecology of the Eldon Group Formations of the Zeehan Area, Tasmania

By

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(Communicated by Prof. S. W. Carey)

With 4 Text Figures and 1 Plate

The lithological units (formations) of the Eldon Group rocks of the Zeehan area have been defined in an accompanying paper (Gill and Banks), and the purpose of the present communication is to (1) give some account of the sedimentation by which these formations came into being, (2) outline their palaeontology, (3) indicate something of the palaeoecology from the fossils and their relationship to the enclosing sediments, (4) discuss the age of the beds and their correlation, and (5) set out the systematic palaeontology concerned, concluding with due acknowledgments and a list of reference works.

1. Sedimentation

Sedimentational Rhythm

Three-quarters of the world's land surface consists of sedimentary rocks, and the percentage is even higher in the area studied. The sedimentary rocks were originally deposited in the southern part of the Tasman Geosyncline (*vide* Browne, 1947, and references; Gill, 1950*a*, for Lower Devonian palaeogeographic map) as free sediments which were subsequently compacted, metasomatized, and regionally metamorphosed.

Treating the formations as wholes, one can observe a definite oscillation in the types of sediment deposited, as summarized in fig. 1. The following points emerge:—

(a) There is an alternation of sediment type, but the heaviest sediments are in the lowest formation of the series, and there is a progressive reduction in the contrast between contiguous sedimentary types. There is an overall reduction in the grain size of the arenaceous components. The generalized curve representing the sedimentary types (taken as groups) is therefore a damped harmonic curve (fig. 1).

(b) The rudite-arenite formations exceed the lutite group in thickness by 900 feet, which is about 10 per cent of the whole. The whole suite of sediments is a siliceous one, even the lutite formations being formed from fine siliceous silts. There are no claystones in the series.

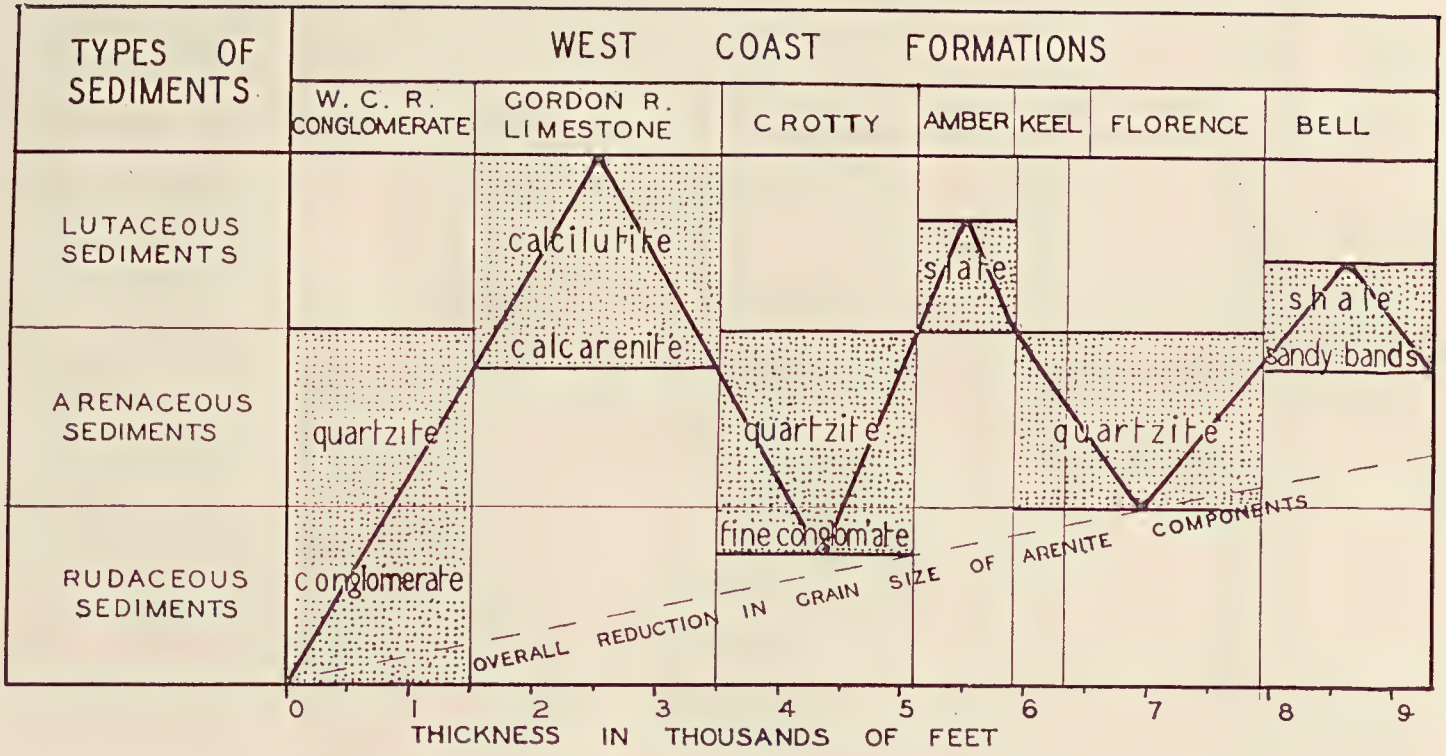

FIG. 1.—Damped harmonic curve representing the sedimentational rhythm recognized when the formations are taken as wholes. The stippled areas indicate in each formation the range of sedimentary types present.

(c) The alternation of sediment type involves considerable thicknesses of rocks, and holds over a large area; it is therefore not an expression of local coastal changes, but a function of geosynclinal movement.

(d) The alternation of sediment type is the fundamental reason for the varied topography, which aids photo-geology.

(e) The alternation is also a help in field geology, especially in the highly faulted areas. For example, if a lutaceous formation is encountered, it can be but one of three. The Gordon River Limestone is calcareous and so easily recognized; this reduces the possibilities to two, which can be distinguished in that the Amber Slate is a very homogeneous formation, while the Bell Shale is characterized by quartzitic bands.

(f) The different types of sediments produced different ecological facies, so that changing faunal characters are correlated with changing sedimentary types.

The alternation just discussed emerges from treating the formations as wholes. As this paper deals particularly with the Eldon Group formations, these are now examined more closely, and the relative information is represented diagrammatically in fig. 2. The graph line shows the rudaceous zone in the middle of the

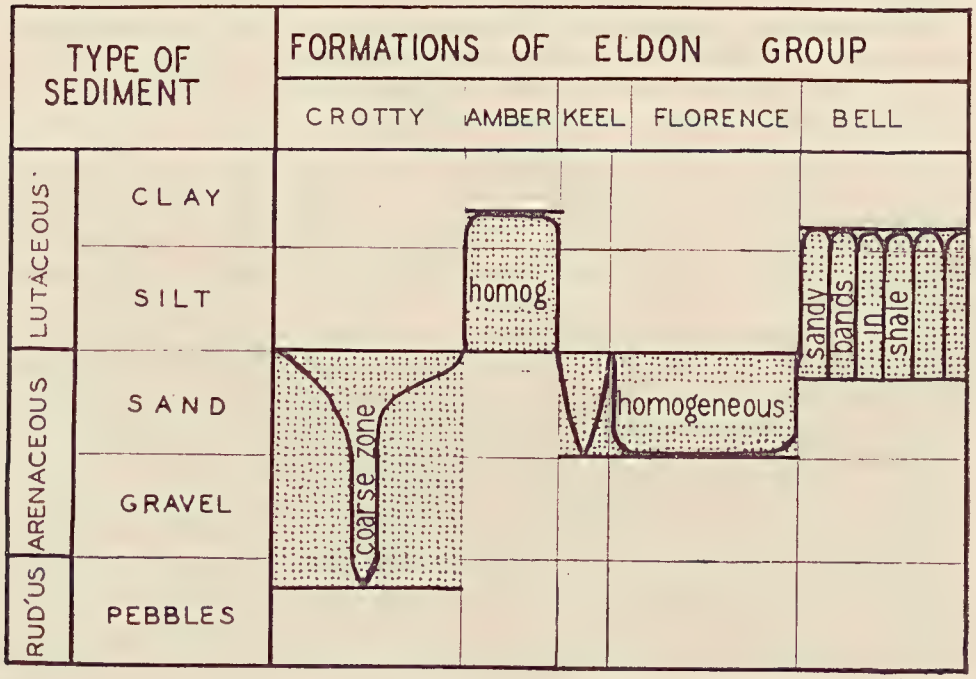

FIG. 2.—Diagrammatic representation of the sedimentational oscillation in the Eldon Group formations, taking into account variation within them. The stippled areas indicate in each formation the range of sedimentary types present.

Crotty Quartzite, the homogeneity of the Amber Slate and Florence Quartzite, that the Keel Quartzite has less arenaceous parts at the top and bottom, and that in the Bell Shale there is some oscillation of conditions with occasional arenaceous bands separating masses of shale or slate.

Probable Disconformity

One of the problems set for study was whether the Crotty Quartzite should be included in the Junee Group with the West Coast Range Conglomerate and Gordon River Limestone, or in the Eldon Group. The writer thinks it should be included in the Eldon Group because:—

(a) There is a probable disconformity between the Gordon River Limestone and the Crotty Quartzite. Fossils so far described from the former are all Ordovician types such as *Tetradium* (Chapman, 1919, Hill and Edwards, 1941), Piloceroid cephalopods (Teichert, 1947), and Asaphid trilobites (Etheridge, 1896, Nye and Blake, 1938). Some of these forms may range into the Silurian, but in spite of wide collecting accomplished in recent years, no Silurian index fossil has been found. On the other hand, a large *Camarotoechia* is herein described from a zone below the median grit band of the Crotty Quartzite. By reason of the coarse matrix and leaching, it is very difficult to obtain recognizable fossils, but in the Eden area (loc. 69), lamellibranchs believed to be *Palaeoneilo* were collected. This genus is recorded widely from the Silurian and Devonian beds of Victoria. On the track to the powerhouse at the Smelters' works on the Crotty Quartzite near Zeehan, a cephalopod was found *non in situ* but undoubtedly belonging to that location; this was identified by Dr. C. Teichert as *Ormoceras* sp., which he states is not an Ordovician type but comparable with Silurian-Devonian forms.

There is thus, apparently, a disconformity between the Ordovician Gordon River Limestone and the Crotty Quartzite which seems to be not older than Upper Silurian. For a demonstration of this disconformity and its extent, fossils will need to be collected in the type area at the top of the limestone.

(b) The Crotty Quartzite introduces a new cycle of erosion and sedimentation. The period of time in which the Gordon River limestone was laid down was one of quiescence. The silts and sands that came from the land mass of the time were limited in quantity, most of the sedimentary materials being calcareous and of organic origin. That the latter should exceed the quantity of terrigenous sediment indicates conditions of relative stability. Occasional arenaceous and lutaceous horizons indicate minor changes in conditions, but the formation as a whole is calcilutaceous judging by the outcrops seen and its physiographic expression. Then there came a change and great quantities of siliceous sand covered the limestone-forming sediments. The movement thus initiated increased in severity, so that coarse sediments of a polymictic type were thrown into the sea, represented now by the grits and fine conglomerate of the Crotty Quartzite formation. They occur at about the middle of the formation, as can be seen both in the Eden and Smelters' sections, dividing it into three members. As described in the accompanying paper (Gill and Banks), the rock is a mixedstone consisting of roundstones (derived from a previous sedimentary cycle) and sharpstones (newly derived), and consisting of clear quartz, milky quartz (pebbles up to 1½" long in the conglomerate), heavy minerals, and pebbles to finer fractions of siltstones (cf. Shrock, 1948, Pettijohn, 1949). This indicates a terrain suffering overall denudation by a new cycle of erosion.

2. Palaeontology

There is a great deal of variation in the amount of recorded life in the formations in the area studied, this is represented diagrammatically in fig. 3. No fossils apart from the tubicolar annelid have been found in the West Coast Range Conglomerate. The Gordon River Limestone is poorly fossiliferous in the

type area (where seen), but at the Smelters' Quarry near Zeehan there is a very rich fauna, represented by a rise in the graph. The Crotty Quartzite is likewise poorly fossiliferous, most outcrops yielding no fossils. However, in spite of preservation being poor, there is a rich palaeontological zone just under the median grit of this formation, both in the Eden area and on the Smelters' ridge near Zeehan, and this is represented by a rise in the graph. Most of the Amber Slate is unfossiliferous, but a couple of rich horizons were found in the railway cuttings south of Zeehan. No fossils were found in the Keel Quartzite in the Eden area, but some were found near Zeehan in quartzite doubtfully referred to this formation on account of its faulted relationships. The Florence Quartzite and Bell Shale are both extremely rich in fossils. Some beds are so rich that the whole face of the rock is covered with fossils, so that originally the layer must have been a coquina.

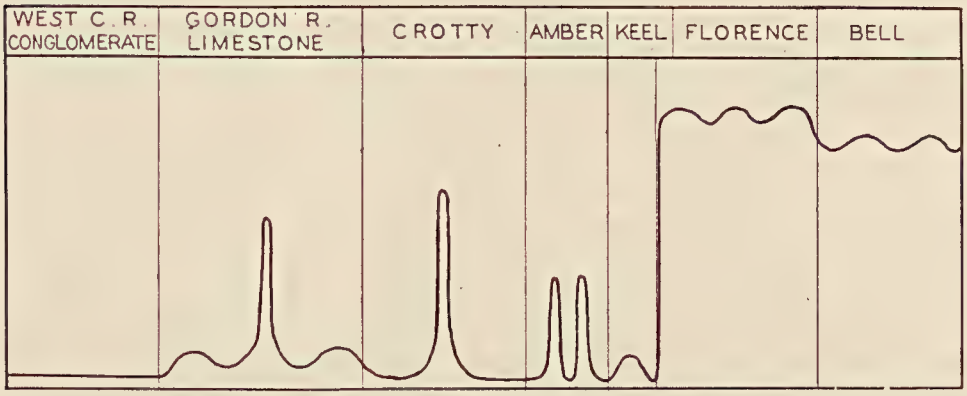

FIG. 3.—Graph representing relative abundance of recorded life in West Coast formations.

Paucity of recorded life does not mean necessarily poverty of life at the time concerned. After describing the activities of various marine scavengers, Dapples (1938) wrote: 'It is shown that these forms constantly ingest such quantities of bottom material that benthonic life may be considered a very active agent in diagenesis . . . Fossiliferous strata are believed to be due to sudden annihilation or rapid burial of benthonic life, whereas many unfossiliferous beds are thought to have been deposited under optimum conditions for animal life.' It is clear that the analogy of modern seas supports this view, and the writer has noted that often fossils can be found in so-called unfossiliferous beds by examining the base of a change in sedimentation. If Dapples' thesis be accepted, then the lower formations are to be regarded as belonging to times of comparatively even sedimentation, while those at the top are to be interpreted as belonging to times of erratic sedimentation.

Crotty Palaeontology

Under the grit band in the Eden area (locs. 68 and 69), numerous remains of lamellibranchs, brachiopods, crinoids, and tubicolar structures were found, but the coarse matrix and strong leaching made decipherment difficult. Undeterminable fossils were found at locs. 65 and 66. However, on the top of the ridge behind the Smelters' works near Zeehan is a richly fossiliferous zone with

Camarotoechia synchoneua as the dominant fossil, and associated with it are occasional toothed lamellibranchs and planospiral gasteropods. Characteristic also is crinoid columnal 1 (Pl. I, fig. 40), which is useful in the field because limited to that formation and it occurs when no other fossils are present. Crushed *Camarotoechia*, lamellibranchs and crinoid columnals occur in the railway cutting at loc. 49. At loc. 48 in the same section are poorly preserved brachiopods, lamellibranchs, and crinoid columnals.

Amber Palaeontology

In the Eden section, the Amber Slate formation is covered with the notorious type of rain forest called 'horizontal', which makes access extremely difficult. Traverses proved the homogeneity of the slates, and a few fossils were found at locs. 63 and 64. The Zeehan-Strahan railway traverses chiefly the Amber Slate and Gordon River Limestone because these are the two formations of the suite which have a low relief physiography. The railway follows the Amber Slate for about 1½ miles N.E. of the 22¼-mile point, and the cuttings there were examined. Most of the exposures proved unfossiliferous, but fossils were found at the following localities. At loc. 47 rhynchonellids, *Loxonema*, bryozoa, and crinoid columnals were collected, and at loc. 41 occurs a band crowded with ostracods. An interesting horizon appears at loc. 42 where a fine sandy band is packed with a fine *Tentaculites* 8 mm. long, and a brachiopod which is probably *Rhenorensselaria*. The brachiopods have suffered badly from crushing, but reconstruction indicates fairly thick shells, i.e., strongly biconvex, of elongate oval outline but sometimes shorter and more rounded. The surface is costellate, about 10 costellae per cm. occurring at the anterior margin, and becoming finer towards the umbo. The full-grown shells are of the order of 2 cm. long and 13 mm. wide, precise measurements being out of the question in the slate. Internally the ventral valve has well-developed teeth and slender dental plates 4-5 mm. long. The dorsal interior has a median septum about 4 mm. long. There are two hingeplates each about 4 mm. wide at widest, separated by a concave crural trough. The steinkern shows the anterior tips of the plates extending anteriorly as fine crura. The cardinal process is ill defined.

Rhenorensselaria occurs in the Lower Devonian of Europe (the genotype comes from the Lower Devonian of Germany) and possibly of South Africa (Cloud, 1942).

At loc. 38 more ostracod bands were noted and *Beyrichia* was identified in a dark grey slate with fine mica.

About 10 miles E. of Queenstown, the Hobart road crosses a ridge west of the Princess River called the Princess Ridge. The rocks consist of finely cleaved slates whose age was unknown but were thought to be probably Pieman (pre-Cambrian). Mr. J. Bradley of the University of Tasmania Geology Department advised Mr. M. R. Banks and myself of the probable occurrence of fossils on the west side of this ridge, and so the outcrops were investigated and some poor fossils collected. I have since examined them and found crinoid columnals of small diameter, the ostracod *Beyrichia (non sensu stricto)*, and rhynchonellid brachiopods—all much distorted by the regional metamorphism the sediments have suffered. These fossils can be fairly closely matched with those occurring at loc. 47 in the Amber Slate in the Eden area, thus establishing a probability that the Princess Ridge slates are of the same age as the Amber Slate.

Florence Palaeontology

The prolific faunules of this formation contrast strongly with the almost unfossiliferous condition of the underlying Keel Quartzite. Both vertically and horizontally the Florence Quartzite is rich in fossils, and hence the large number of localities for this formation. *Notoconchidium florencensis*, *Protoleptostrophia plateia*, and *Eatonia (Eatonia) pleonecta* are index fossils for this formation, being limited to it as far as present knowledge goes.

Bell Palaeontology

This richly fossiliferous formation is characterized by the incoming of a variety of new forms. This is partly due to its variety of facies, resulting from small oscillations of relative sea level presumed to be due to the onset of the orogeny which concluded Bell sedimentation. *Notanoplia*, *Plectodonta*, *Leptocoelia*, *Meristella*, *Eospirifer*, and *Proetus* are examples of genera which appear for the first time in the Bell Shale, judging by the collecting done so far. These forms and crinoid columnal 2 (Pl. I, fig. 41) are index fossils of the formation. Some of the genera named have facies limitations, but *Notanoplia* is found in Victoria in matrices varying from the finest siltstones to coarse grits, representing a wide variety of facies. Its incoming in the Bell Shale is therefore probably a function of time and not of facies.

3. Palaeoecology

The Eldon Group as a whole presents an arenaceous facies suggesting the dominance of near-shore conditions. All the fossil localities examined presented thanatocoenoses—places where those forms of life were buried and not where they lived, for once marine animals die they become sedimentary materials. Common to all the formations are the crinoids, although nothing more than columnals and an occasional plate were found. There appears to be some correlation between thickness of the column or stem and the coarseness of the sediment. Fine-stemmed forms occur in the Amber Slate where thick columns are entirely absent. The medium sized columns occur in the shales and quartzites of the Florence and Bell formations. The very thick columns as represented by crinoid columnal 1 occur only in the coarse zone of the Crotty Quartzite. The coarse sediments and strong cross-bedding indicate fast currents, and strong columns were needed, while the converse held for the quiescent conditions of the Amber Slate.

It is interesting to note in the fine sedimentation of the Amber Slate the coming of a brachiopod of Rhenish facies like *?Rhenorensselaria* once sandy conditions prevailed, even though for a short time. Swarms of water-fleas (Ostracoda) teemed in the Amber seas, and changes in conditions resulted in their burial in countless numbers. Three such ostracod bands were noted in the traverse along the Zeehan-Strahan railway north of the 22-mile post.

The abundant fossils of the Florence Quartzite prove seas teaming with life. There are beds consisting of little but masses of crinoid columnals of about $\frac{1}{8}$" diameter. There are such millions of them that they present a picture of a sandy sea-floor covered with a waving garden of sea-lilies (Crinoidea). The matrix proves the nature of the sea-floor and the cross-bedding shows the water was fast moving. In some beds there are just crinoid columnals and a rhynchonellid, so that the latter may have lived attached to the crinoid stems. Other zones

again are full of branching bryozoa, indicating that as the dominant form of life, and calling up a picture of a 'coral' sea. Yet other strata are packed with brachiopods. Lamellibranchs are few, but a large actinopterid growing up to three or four inches across is a common fossil, but always broken. It is curious that there should be so few lamellibranchs since they constitute a characteristic phase of the Rhenish facies. Another negative feature worthy of comment is the poverty of trilobites in the Eldon formations of this area. Brachiopods, crinoids, and bryozoa appear to have been the dominant forms of life. Graded bedding was recognized in some places in the Florence Quartzite, and proved useful in indicating the top and bottom relationships in overturned beds (cf. Shrock, 1948).

In the Bell Shale, oscillation of sedimentary type brought oscillation of ecological conditions with amazing variety in faunules. It is possible to walk across country at right angles to the strike and encounter succeeding faunules which are almost mutually exclusive. If these zones can be proved to be at all extensive, they will admit of fine and accurate subdivision in the formation. This would be instructive palaeoecologically and useful to mining companies. Brachiopods dominate in this as in the other formations, and although lamellibranchs are commoner, they are still relatively rare. Crinoids are common, but do not occur in great masses as they do in the Florence Quartzite. Vascular land plants indicate that there was a thin vegetative cover on at least part of the land surface of the time. Berry (1945) regards these early plants as a bog flora.

4. Age and Correlation

As there is some difference of opinion as to where the Siluro-Devonian boundary should be drawn, I should state that I follow Stamp (1923*a*, 1923*b*) in regarding the base of the Lower Devonian as the base of the Ludlow Bone Bed of the Welsh Borderland, which in turn is considered the equivalent of the base of the Gedinnian on the Continent. White (1950) has recently provided new evidence and discussed the Siluro-Devonian in the type area, arriving also at the conclusion that the Bone Bed is the best base for the Devonian, a view moreover 'strongly advocated on the Continent'. The North American equivalent of the Siluro-Devonian junction is apparently the base of the Helderberg Stage. The Lower Devonian in North America comprises the Helderberg, Oriskany, and Onandaga according to Cooper *et al.* (1942).

The Bell Shale contains *Plectodonta bipartita* and *Chonetes* aff. *ruddockensis* which are index species of the lower part of the Yeringian Group (Lower Devonian) of Victoria (Gill, 1945). These forms, with *Notanoplia*, *Notoleptaena*, *Proetus euryceps*, *Pleurodictym megastomum*, and '*Lindstroemia ampla*' constitute a fauna which is characteristic of the Kinglake West District of Victoria. *Parmorthis allani* is a species from the Lower Devonian of New Zealand. *Maoristrophia*, known only from the Lower Devonian of New Zealand and Australia, *Meristella*, and *Leptocoelia* also indicate a Devonian age. The palaeontology has not been studied in sufficient detail yet for close correlations to be proved, but the general correlation with the Yeringian of Victoria is indubitable.

The Florence Quartzite is also classified as Lower Devonian because it contains *Notoconchidium*, a genus which is an index fossil of the Lower Devonian Mt. Ida Beds of the Heathcote District of Victoria (Thomas, 1937), and proves now to be also an index fossil of the formation named. *Protoleptostrophia*, *Maoristrophia*, and *Eatonia (s.s.)* also occur and these are Devonian genera.

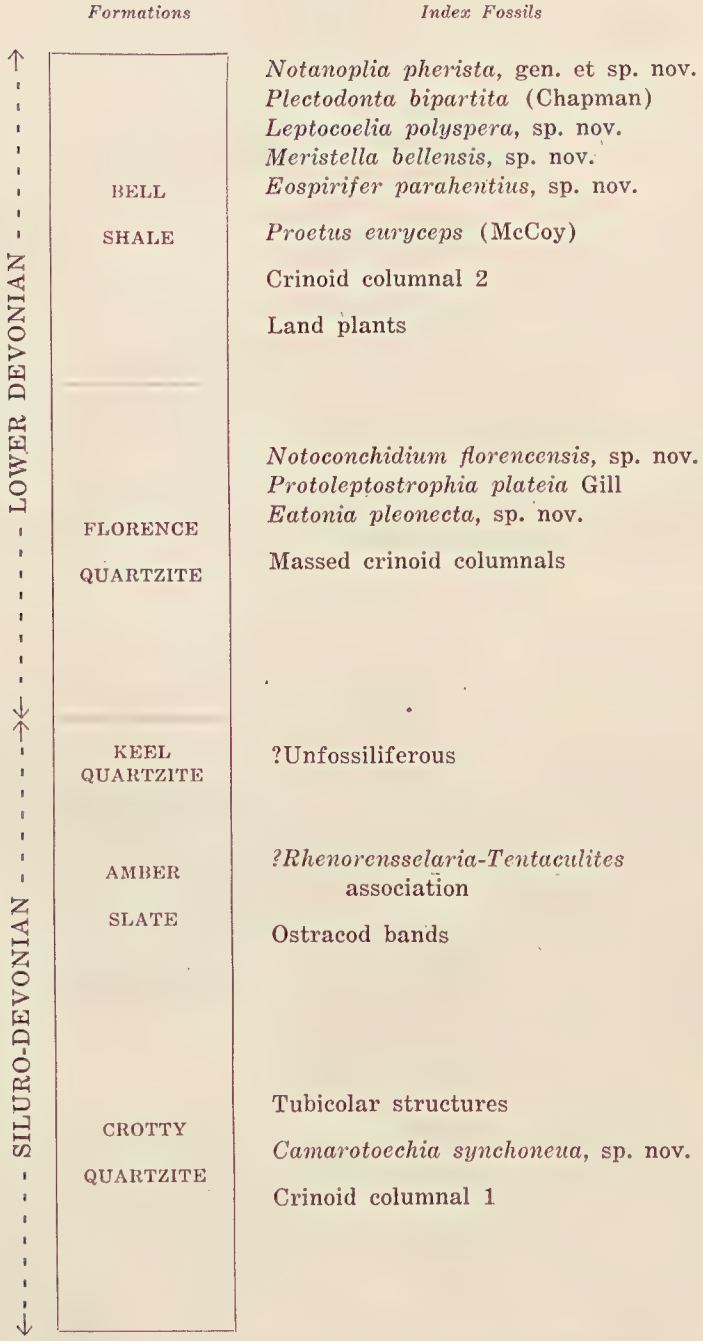

FIG. 4.—Age and index fossils of the Eldon formations in the Zeehan area, Tasmania.

Through lack of decisive evidence, the age-determination of the three underlying formations is left in abeyance. If the occurrence of the genus *Rhenqrensselaria* is confirmed in the Amber Slate, then both the Amber Slate and the Keel Quartzite are Devonian.

5. Systematic Palaeontology

Plantae

In an indurated siltstone at locality 16, beside the Little Henty River near Zeehan, there occur numerous fragments, generally only $\frac{1}{8}$" to $\frac{1}{4}$" long, of carbonized plant stems which show evidence of vascular tissue (N.M.V.* 14825). A similar bed was found on the track to the Sunshine Mine. These fragments are interpreted as land plants, and are probably of the type recorded from Warrentinna in Tasmania (Cookson, 1937), and from Victoria (Lang and Cookson, 1935, Cookson, 1935, 1945, 1950).

Marine fossils occur in the same stratum with the land plants, and so the latter must have been washed into the sea. This suggests that there was a Lower Devonian river in this vicinity.

Echinoderma

Crinoid Columnal 1

Pl. I, fig. 40

Circular in outline, 16 mm. in diameter and 4 mm. thick. The central canal is 5·5 mm. in diameter. Natural sections show that a cross-section along a diameter has a planate-oval outline, i.e., the dorsal and ventral surfaces of each columnal are curved. The central canal in such a section has a biconvex outline.

Formation. Crotty Quartzite.

Comment. The figured specimen is N.M.V. 14843 and comes from locality 19, which is the Smelters' sand quarry, near Zeehan. The form is abundant and a characteristic fossil of that formation.

Crinoid Columnal 2

Pl. I, fig. 41

Circular in outline, 9 mm. in diameter and about 1 mm. thick. Perimeter scalloped. Central canal a little less than 1 mm. in diameter; appears to be subpentagonal in outline. Around the canal is a circle of very short radial fine ridges about 1 mm. from the centre of the columnal. Around the perimeter of the columnal are 20 radial ridges about 1·5 mm. long. (N.M.V. 14822.)

Formation. Bell Shale.

Comment. In the field these columnals were found to be useful as a Bell index fossil because they occur sometimes when other fossils are absent.

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* N.M.V. = National Museum of Victoria, Melbourne.

Coelenterata

'Lindstroemia ampla' Chapman

Some difficulty has been experienced in dealing with the fossil corals referred by Chapman (1925) to *Lindstroemia*. In practice, we have distinguished in the Yeringian beds of Victoria two kinds, the first having an elongate corallum which we have called *L. yeringae* and a second with a comparatively short broad corralum which we have called *L. ampla*. The corals are preserved only as casts and determination is difficult. However, the recognition of the two types of corallum is easy, but whether these two groups are true species and how closely they correspond with Chapman's species has yet to be determined. In the sense of the above form diagnosis, *L. ampla* occurs at localities 1 and 5 at Zeehan.

Genus **Pleurodictyum** Goldfuss, 1829

Pleurodictyum megastomum Dun

Pl. I, fig. 37

See Gill, 1942, for synonymy to that date.

Pleurodictyum megastomum Hill, 1942, p. 8, Pl. 2, fig. 5.

Pleurodictyum megastomum Gill, 1948, p. 66, Pl. VIII, fig. 13.

Locality. Right bank of the Little Henty River, about one mile S.E. of Zeehan, locality 16. The localities mentioned in this paper are to be seen on the map in the accompanying paper by Mr. M. R. Banks and the writer.

Formation. Bell Shale.

Comment. Pleurodictyum megastomum is a characteristic fossil of the Bell Shale at Zeehan. Dr. Dorothy Hill (1942) described this species from an unknown locality in Tasmania, and commented that Etheridge (1896) figured a coral from Zeehan which might well be this species. The specimens described were in a blue-grey shale, which is a characteristic lithological type of the Bell Shale formation. *P. megastomum* has also been collected from near the top of the Florence Quartzite at Zeehan (loc. 12), and from localities 1, 5, 6 in the Bell Shale.

Thomas (1947, p. 36), in commenting on West Coast stratigraphy, said that 'Some of the forms, however, e.g., *Pleurodictyum*, would indicate a higher horizon than the authors would give their "Silurian" beds which may thus extend into the Lower Devonian and would be comparable with the Yeringian of Victoria'. He thus regarded *Pleurodictyum* as a probable index of Devonian age, as also did Hill (1943, p. 58), who in discussing Australian Palaeozoic stratigraphy, referred to the presence of *Pleurodictyum* at Zeehan, and stated, 'The age of the Zeehan shale is thus probably Lower Devonian, though a Ludlovian horizon is still possible'.

The figured specimen is N.M.V. 14813.

Annelida

The Tasmanian geological literature is steeped in references to 'tubicolar sandstone'. The writer has seen the structures referred to in the West Coast Range Conglomerate, in an outcrop of quartzite in the Gordon River Limestone (loc. 55), and in the Crotty Quartzite in a number of localities (e.g., loc. 69). Bryozoan, crinoidal, and other structures apparently have been confused at times with true annelid remains, some at any rate of which appear to belong to the genus *Sabellarifex* Richter. These fossils require proper study, but a few relevant comments will be made here.

Professor Richter wrote three interesting and valuable papers (1920, 1921, 1927) drawing attention to large, flat-topped reefs in shallow North Sea waters off the coast of Schleswig-Holstein consisting of masses of straight, vertically disposed, arenaceous tubes built by the annelid *Sabellaria alveolata* Linn. (see also Galeine and Houlbert, 1922), and indicating their close similarity to fossil worm tubes in rocks from Cambrian to Devonian age. *S. alveolata* builds closely-packed vertical tubes (locally known as sand-coral) cemented enough to form pebbles when broken up. It grows only on sandy bottoms free from mud, and other macroscopic forms of life are usually absent. A related species has loosely intertwined tubes. Richter has drawn the parallel in Palaeozoic rocks with *Scolithus* whose simple tubes are very straight, unbranching, vertical to the old sea-floor, crowded, and limited to nearly pure sandstones devoid of other fossils. Prof. Richter set out a taxonomy for fossil annelid remains, and split off from *Scolithus* a new genus *Sabellarifex* to accommodate the forms which show slight undulations and less strictly parallel growth and a tendency to be less crowded. He described a new species, *Sabellarifex eifliensis*, from the Lower Devonion Koblenzquartzit of Germany (Richter, 1920). These annelids therefore range in age from Cambrian to Devonian. Richter's papers contain much of ecological value, and a précis of them has been published in English by Bucher (1928).

Brachiopoda

Genus **Notoconchidium** Gill, 1950

Notoconchidium florencensis, sp. nov.

Pl. I, figs 7-9

Type Material. 1. HOLOTYPE consisting of a dorsal valve preserved as a steinkern (N.M.V. 14799) and an external mould (N.M.V. 14798) in a whitish quartzite with a little yellowish-brown iron stain. This is a typical surface lithology of the Florence Quartzite formation. The type specimens are from the cutting on the east side of the Silver Bell railway station yard (loc. 15), near Zeehan, about 230 feet south of the centre of the road crossing the railway at the north end of the station.

Formation. Florence Quartzite.

Description. HOLOTYPE dorsal valve sub-triangular in outline, strongly convex, the midline profile rising about 1 cm. above the plane joining the posterior and anterior margins. The sides of the valve are deflected at right angles to the above plane, as is typical of this genus. Length in plan 1·9 cm., but following the profile 2·8 cm.; greatest width 2 cm. Hingeline narrow and beak blunt. Anterior commissure rectimarginate. Shell very thick in the posterior region; costate, but relatively smooth at the umbonal end. The costae appear also on the lateral and anterior areas of the inside of the valve, as is shown by the steinkern. The costae are low, and rounded in cross-section; the interspaces are about a quarter of the width of the costae. There are six costae per cm. at the anterior margin.

Septal plates diverge at first at the umbonal end, and then converge. They reach three-quarters of the way down the valve, and are thick and deep. The spaces between the septa and the lateral walls of the valve are filled with callists which are 4 mm. thick next the septa (their thickest part). The median septum

has been overgrown near the umbo with secondary deposition, and there is a median ridge between the septa at their anterior end. Indistinct knobs or short ridges occur at the posterior ends of the septa, and these are regarded as branchial supports.

Comment. The genus *Notoconchidium* was established on fossils from the Heathcote District of Victoria (Gill, 1950*c*), where it is an index fossil of the Mt. Ida Beds (Lower Devonian), is limited to that formation, and occurs in a sandy facies. Likewise, *N. florencensis* is an index fossil of the Florence Quartzite, is limited to that formation, and occurs in a sandy facies. The new species is distinguished readily from the genotype by its more squat proportions and its coarser costation. After much search there has been located one of the type specimens of Etheridge's (1883) *Pentamerus tasmaniensis*, which is reg. no. B361 of the Tasmanian Museum and Art Gallery, Hobart, and it is probable that the other specimens will also be found. The specimen now figured (Pl. I, figs 10-11) is Etheridge's Plate II, fig. 1 (fig. 2 is on the other side of the same specimen), and I suggest this be accepted as the lectoholotype. Etheridge himself was apparently struck by the unusual features of this brachiopod as he comments (p. 159), 'The commonest, and at the same time the most interesting fossil met with in the specimens under description, is undoubtedly a Pentamerus, although at first sight its affinities were certainly obscure'. Etheridge seems to have been puzzled at the differences between the various dorsal valves as he refers to the original of fig. 1 as a 'modification' (p. 160). Fig. 1 represents an older valve with the internal structures considerably thickened. A series of growth stages of both valves of the genotype has been figured (Gill, 1950*c*). Etheridge's figs 3 and 4 are not of a ventral valve, as stated (p. 162), but of a dorsal valve. Figs 2, 10, and 16 are rhynchonellids.

Notoconchidium tasmaniensis has proportions similar to those of *N. florencensis*, but a finer costation comparable with that of the Victorian form, *N. thomasi*. One feature in *N. tasmaniensis* not seen in the other two species is the bifurcation of the costae. In B361 the anterior margin is not complete, but along the sides it is noted that about half the costae bifurcate, viz., those on the posterior end of the deflected border (Pl. I, fig. 10). Bifurcated costae have not been seen in either *N. thomasi* or *N. florencensis*. *N. tasmaniensis* was collected from pebbles in a Permian glacial conglomerate at Table Cape, near Wynyard, North Tasmania, and the material is thought to have come from an area to the S.S.W. (David, 1908). David described the matrix as 'an ochreous brown soft sandstone', a description which fits very well weathered Florence Quartzite.

In the Zeehan district *N. florencensis* is very abundant but a ventral valve is hardly ever seen. None good enough to figure was discovered. The absence of ventral valves is apparently due to the fact that during life the dorsal valve is considerably thickened and so strengthened over a considerable portion of its area, while in the ventral valve only a small area at the umbo is so fortified. All large shells in the Florence Quartzite have suffered severely from the action of currents, and it would appear that the ventral valves of *Notoconchidium* seldom escaped harm before being finally buried in the sediments. It has been noted that although *N. thomasi* is very common in the Mt. Ida Beds of Victoria, ventral valves are comparatively rare.

A series of specimens covering the various growth stages of *N. tasmaniensis* and *N. florencensis* are now needed for an adequate comparison of the species with the genotype. *N. florencensis* is common in the Florence Quartzite both throughout its stratigraphical thickness and its lateral extent. A detailed examination was

made of the cutting at the Silver Bell railway station, which is in Florence Quartzite, and *Notoconchidium* was collected all along the 800 feet of exposed beds. It is not found in any of the other formations. By its ready identification, its abundance, its occurrence both vertically and horizontally in the formation, and its limitation to the formation, *N. florencensis* constitutes an ideal index fossil of that formation, and hence its name. Going north in the Tasman geosyncline one meets *N. florencensis*, then *N. tasmaniensis*, and finally *N. thomasi*, the central one (on present knowledge) appearing to be intermediate between the other two. *N. tasmaniensis* (under its original name of *Pentamerus*), is one of the most quoted fossils in the Tasmanian geological literature—e.g., Johnston, 1888 (who also figured it after Etheridge, 1883), Twelvetrees, 1908, David, 1908, Basedow, 1909, Twelvetrees and Ward, 1910, Nye and Lewis, 1928, Nye, Blake, and Scott, 1938, and Thomas, 1947 (where the species is wrongly attributed to Johnston).

Notoconchidium was collected in the Zeehan district from localities 9, 15, 23, 24, 25, 26, 27, 32, 35, 51, 52, 53, 60, 61.

Genus **Eatonia** Hall, 1857

Subgenus **Eatonia** McLearn, 1918

Eatonia (Eatonia) pleonecta, sp. nov.

Pl. I, figs 33-35

Type Material. 1. HOLOTYPE consisting of a steinkern (N.M.V. 14840) of both valves preserved in whitish sandstone (leached quartzite) from locality 23, Smelters' ridge, S.E. of Zeehan.

2. PARATYPE consisting of the steinkern (N.M.V. 14841) and external mould (N.M.V. 14842) of another ventral valve in the same matrix and from the same locality.

Formation. Florence Quartzite.

Description. 1. HOLOTYPE. Shell small, biconvex with dorsal valve the deeper, subcircular in outline, 1 cm. long and 1 cm. wide; two valves together 6 mm. thick. Ventral valve with median sinus, but not deep as in *Eatonia (Pareatonia) euplecta*, and dorsal valve with corresponding fold. Anterior commissure uniplicate. Valves costate, about 10 costae on each valve; there are two on the ventral sinus. Costae well developed anteriorly, but valves smooth on the umbo. Ventral muscle field deeply set, the posterior lateral areas being considerably thickened. The diductor scars are sub-parallel, but a little wider than in the paratype; long, extending 7 mm. from the umbo, i.e., more than half the length of the valve.

Dorsal valve with strong median septum, which extends more than half the length of the valve. The costae of the fold begin about half way down the valve, which is the anterior to the comparable point in *Eatonia (Pareatonia) euplecta*. Large erect cardinal process with myophore having two prongs, 1 mm. apart, which jut into the cavity of the ventral valve. These prongs are seen as holes in the steinkern.

2. PARATYPE ventral valve convex, subcircular in outline; 9 mm. long in plan down the midline to the centre of the sinus, which is about 1 mm. deep, giving an overall length of 1 cm. Following the profile of the midline, the length is 12·5 mm. The greatest width, which is about half way down the length of the valve, is 11 mm. In plan, the muscle field reaches a point 7 mm. from the umbo, i.e., more than half the length of the valve. The adductor scar is heart-shaped and 2 mm. long.

Comment. The subgenus *Eatonia* is characterised by a decline in the fold and sinus, radial striae superimposed on the costae, and an elongate ventral muscle field (McLearn, 1918, 1924). In *Eatonia (Eatonia) pleonecta* the fold and sinus is much shallower than in *Eatonia (Pareatonia) euplecta*, the radial striae can be seen in the external mould of the paratype, and the ventral muscle field is elongate, reaching well past half way down the length of the valve. In general proportions the new species simulates *E. (Pareatonia) euplecta* (Gill, 1948*a*), but is very readily distinguished by its more numerous costae, and so the trivial name is taken from the Greek word *pleonecteo* meaning 'to have more'.

The new species is also common at locality 23, which is at the base of the Florence Quartzite.

Genus **Leptocoelia** Hall, 1859

Leptocoelia polyspera, sp. nov.

Pl. I, figs 25-28, 38

Type Material. 1. HOLOTYPE consisting of the steinkern of a ventral valve (N.M.V. 14795) preserved in a light-grey indurated siltstone from locality 16.

2. PARATYPE consisting of the steinkern (N.M.V. 14796) and external mould (N.M.V. 14797) counterparts of a dorsal valve in the same matrix and from the same locality.

Formation. Bell Shale.

Description. 1. HOLOTYPE ventral valve longer than wide, and greatest width posterior to transverse midline. Convex, but not evenly so, the transverse midline profile being almost an obtuse angle, while the longitudinal midline profile is evenly curved, rising nearly 3 mm. above the plane uniting the anterior and posterior margins. Hingeline short and curved. Length of shell 9·5 mm. and greatest width 9 mm. Beak prominent, the shoulders on each side falling away evenly to constitute an angle of the order of 140°. Cardinal angles well rounded. Median sinus commences a little past half way to the anterior margin, i.e., at about the point where the muscle field ends. Commencing at the same place is a costa which occupies the middle of the sinus. Examination of a number of specimens shows that fifteen costae is usual, but the full number does not show on the steinkern. Costae rather rounded in cross-section, and wider than the interspaces. The ends of the costae are arched at the anterior margin so that the anterior commissure is wavy; it is also uniplicate by reason of the sinus. In the steinkern is a fine ridge near the anterior margin and almost parallel to it; this is not limited to the holotype but commonly seen in other steinkerns. It does not show on the external moulds and so is a ridge on the interior of the valve and not a crinkle in the shell itself.

Teeth large and without dental plates; the outline of each tooth base is the shape of an arrowhead with the tip pointing towards the umbo; the tooth prong is at the tip of the arrowhead. Interarea small, smooth. The muscle field is well defined, there being three areas of excavation, viz.:—

(a) Flabellate diductor field bounded by a fine ridge anteriorly and laterally; margin slightly scalloped. The carinae bounding the field turn inwards and posteriorly to the midline, coalescing with the linear but well-defined median septum. This point is 7·5 mm. from the tip of the beak.

(b) Heart-haped adductor field well-excavated, and more so posteriorly than anteriorly. Divided by the median septum. Scar 1·25 mm. long and 1 mm. wide; the posterior end is 3·5 mm from the tip of the beak.

(c) At the beak there is an excavated area reaching 2 mm. from the tip, and separated from the diductor field by a ridge which appears as a furrow in the steinkern. This field is bisected, like the others, by the median septum. It is interpreted as the place of attachment of the pedicle muscle.

2. PARATYPE dorsal valve 9 mm. long overall, and 7 mm. wide; slightly convex in that most of the valve is planate but the antero-lateral and lateral borders are deflected ventrally. The area corresponding to the ventral sinus is not deflected but continues on in the plane of the main part of the valve, and thus constitutes the homologue of the dorsal fold that in medially folded brachiopods usually corresponds to the ventral sinus. As the median costa characterizes the ventral sinus in this species, so two costae characterize the dorsal 'fold', one being on each side of the midline. On each side of this pair are six costae, making a total of fourteen. A little more than half-way down the valve is a concentric furrow which affects the interspaces only, i.e., it does not interrupt the costae. A comparable structure is seen in *L. flabellites* as figured by Cooper in Shimer and Shrock, 1944, Pl. 121, fig. 26. A parallel with the internal ridge of the ventral valve (situated almost on the anterior margin) is a short ridge on the interior of the dorsal valve which affects only the two costae on the 'fold'. Right at the margin, on the anterior side of the ridge, the two costae turn ventrally. They thus would occupy in the live animal the two spaces on each side of the ventral median costa, ensuring that no foreign body entered the mantle cavity. Interspaces wider than costae, contrasting thus with the ventral valve where the costae are wider. This likewise is a provision ensuring that the anterior margins of the two valves are wholly contiguous when the shell is closed.

The cardinalia are set on a thickening of the valve occupying the postero-central part, and projecting into the ventral valve. From this there extends anteriorly a fine median septum extending about half way to the anterior margin. On each side of the midline at the posterior end of the septum are excavations interpreted as muscle attachments. Immediately posterior to these are the nodose crural bases. The cardinalia constitute a solid component with large somewhat tear-shaped sockets on the outer sides for the accommodation of the large teeth of the ventral valve. Between these are two recesses separated by a fine median septum, and this central block stands out a little from the sockets at the sides, thus forming a kind of cardinal process which may be described as bilobed.

Comment. Leptocoelia often occurs in great numbers in the Bell Shale, and so is given the trivial name *polyspera* from the Greek word meaning 'spread far and wide' and so 'numerous'. Chapman (1920) referred to the closely related genus *Coelospira* a brachiopod from Gippsland, Victoria *(C. australis)*. His specimens show no internal structures (thus making determination uncertain), but the external form is quite different from that of the species now described. *L. polyspera* differs from the genotype, *L. flabellites*, in its different outline, greater number of costae, and in the construction of the cardinalia, including the possession of a bilobed instead of a quadrilobate cardinal process. The excavation of the beak area of the interior of the ventral valve also seems to be a point of difference.

Genus **Eospirifer** Schuchert, 1913

Eospirifer parahentius, sp. nov.

Pl. I, figs 1-6

Type Material. 1. HOLOTYPE ventral valve steinkern, N.M.V. 14792 coated with yellowish brown iron oxide and preserved in a light grey siltstone from locality 16, on the right bank of the Little Henty River about a mile S.E. of Zeehan.

2. PARATYPE consisting of the steinkern (N.M.V. 14793) and external mould (N.M.V. 14826) of a dorsal valve similarly preserved and from the same locality.

3. HYPOTYPE ventral valve on same slab as the external mould of the paratype (N.M.V. 14826). It is the half exo-skeleton of a more developed animal.

Formation. Bell Shale.

Description. 1. HOLOTYPE ventral valve 2·4 cm. greatest width 2·0 cm. along the hingeline; length 2·4 cm. including the beak. The latter juts about 2 mm. beyond the hingeline, which is straight. Cardinal angles obtuse, and anterior margin rounded. Anterior commissure uniplicate; this plication forms an arc and is not subquadrate as in the genotype (St. Joseph, 1935). Valve convex, the midline profile rising about 4 mm. above the plane joining the anterior and posterior margins of the valve. Ventral muscle field strongly excavated, and reaching 13 mm. from the beak, i.e., about half way down the arched surface of the valve. The field is bounded on each side by strong dental plates 8 mm. long; these continue round the anterior end of the muscle field as very faint linear carinae. The palintrope is a strong incurved plate over 0·5 mm. thick near the umbo; interarea finely striated transversely. Well-defined median longitudinal sinus, 5 mm. wide in the middle of the valve and about 1·5 mm. deep; the transverse profile is curved. Fine costellae of the exterior surface show also on the steinkern; they number about 55 per cm. The delthyrium is about 5 mm. wide at the hingeline, i.e., one quarter of the length of the hingeline.

2. PARATYPE steinkern of dorsal valve is somewhat sheared but of similar size and proportions to the ventral valve, but not quite as convex. Four or five low plicae are present on each side of the median fold. The median longitudinal fold has a rounded cross-section like that of the sulcus in the ventral valve. The costellation is likewise similar. A low linear median septum extends for 1·5 cm. down the midline. The hinge plate is divided, each section being about 3 mm. wide and 0·5 mm thick; supported by slightly divergent lamellar crural bases.

3. HYPOTYPE ventral valve is more developed showing deeper excavation of the muscle field, and stronger dental plates. Mesially, immediately under the umbo, is a short ridge 3 mm. long; St. Joseph (1935, p. 321) refers to a similar structure in the genotype, commenting that 'the genus shows the weakest cuseptoid development of any of the forms included in Frederic's group Elythenae' (1926).

Comment. Because of the shearing of the rocks containing these fossils, it is difficult to find a complete and undistorted specimen. The shells are thin and readily yield to the shearing pressures; the distortion makes many valves look more transverse than they really are, and develops puckers of varying dimensions. It is difficult to determine the precise degree of plication of the valves.

Two groups of *Eospirifer* have been noted in the Lower Devonian rocks of Tasmania, Victoria, and New Zealand, viz.:—

1. Those with a median fold having a squarish cross-section. To this belong the forms figured by Shirley (1938) from the Baton River Beds of New Zealand, and those figured by the writer from Victorian localities in the Lilydale District (1942) and in Gippsland (1949*c*).
2. Those with a median fold having a rounded cross-section. To this group belong *E. parahentius* and undescribed forms from Lilydale and Mooroolbark, Victoria.

The new species described above is very common at locality 16. It is so characteristic of this faunule beside the Little Henty River that it has been called *parahentius* (Greek *para* beside, and the name *Henty*).

Genus **Meristella** Hall, 1860

Meristella bellensis, sp. nov.

Pl. I, figs 14-18

Type Material. 1. HOLOTYPE consisting of the steinkern of a ventral valve (N.M.V. 14823) in fawnish grey indurated siltstone from locality 16, S.E. of Zeehan. Numerous other valves occur on the same slab, and one of these has been selected and figured as a HYPOTYPE. It is another ventral valve.

2. PARATYPE consisting of the steinkern of a dorsal valve from the same bed as that yielding the holotype.

Formation. Bell Shale, and hence the trivial name.

Description. 1. HOLOTYPE ventral valve 2·5 cm. long and 2·1 cm. wide in plan. The median longitudinal profile rises 0·5 cm. above the plane uniting the anterior and posterior margins. Oval in outline longitudinally. Very deeply impressed muscle area, this being a very mature specimen. Muscle field reaches 1·5 cm. down the midline from the tip of the beak, i.e., more than half way. Weak dental plates present in both holotype and hypotype, but the plates become somewhat overgrown with the internal thickening of the postero-lateral areas. Teeth strong. The counterpart of the holotype is not preserved, but other specimens prove the exterior to be smooth except for growth lines.

The HYPOTYPE illustrates a full-grown ventral valve, but not so thickened as the holotype, where the various structures are accentuated.

2. PARATYPE dorsal valve 2 cm. long and 1·5 cm. wide in plan. Muscle field deeply impressed, and is 1·4 cm. long with a width of 6 mm. Median septum comparatively wide on the floor of the shell and narrowing upwards; high anteriorly. The septum gradually recedes so that it is merged with the floor of the valve by the time the anterior margin of the muscle field is reached. Hinge-plate divided by median groove. Deep teeth sockets.

Comment. There are 16 individuals of this species crowded on the slab which preserves the holotype. The species seems thus to occur in profusion in certain horizons but is absent from others that do not seem to present a very different facies. This suggests that it was rather sensitive to environment. *Leptocoelia polyspera* and crinoid columnal 2 are also present on the same piece of rock. On the small piece with the paratype, there is another specimen of *Meristella*, a few *Beyrichia*, and numerous crinoid columnals including no. 2.

The new species has many points of resemblance with *Meristella nasuta* (Hall, 1867, Pl. 48), which is of Onandaga (Lower Devonian) age. There are many small differences, but the striking one is the difference in size and development of the ventral and dorsal muscle fields. *M. bellensis* is genetically related to McCoy's *Pentamerus australis* (1877) which is a *Meristella*. *M. bellensis*, or a closely related form, occurs in the Baton River Beds of New Zealand.

Genus **Plectodonta** Kozlowski, 1929

Plectodonta bipartita (Chapman)

Pl. I, figs 21-23

Chonetes bipartita Chapman, 1913, pp. 104-105, Pl. 10, figs 8-10.

Noting that this species was referred to the wrong genus, the writer (1945) referred it provisionally to *Stropheodonta*, and then later to *Plectodonta* (1948*b*, p. 13). Recently, Dr. Ida Brown (1949) has referred Mitchell's *Stropheodonta davidi* from New South Wales to *Plectodonta*, and redescribed it. The species is closely related to *P. bipartita*, but lacks the bipartition which is so characteristic of it. However, Dr. Brown's fig. 1*a* exhibits a tendency thereto. The Tasmanian specimens are strongly bipartite.

P. davidi is Upper Silurian and *P. biparita* Lower Devonian, and it is conceivable that the latter developed out of the former. The genus is known from the Silurian of North America, and the Silurian and Devonian of Europe (see Solle, 1938, Volk, 1939, Mailleux, 1941, for Devonian species).

The figured specimens are a steinkern of a ventral valve (N.M.V. 14804), the steinkern of a dorsal valve (N.M.V. 14807), and the external mould of another dorsal valve (N.M.V. 14810). All are from locality 1.

Genus **Chonetes** Fischer, 1837

Chonetes aff. ruddockensis Gill

Pl. I, fig. 36

In the Bell Shale at locality 1 occurs a *Chonetes* (N.M.V. 14804) which is comparable with the one named above from the Lower Devonian of the Lilydale District, Victoria. It has similar proportions and prosopon (for term see Gill, 1949*d*) but is more obese and a little larger than is usual for that species. However, it is not as large as *C. cresswelli* nor has it the median sinus of that species. The spines have yet to be seen on the Tasmanian form, and these will help to define its relationships.

Genus **Notanoplia** gen. nov.

Genotype **Notanoplia pherista**, gen. et sp. nov.

Diagnosis. Chonetoids without spines on the ventral margin; small. Planoconvex, or with the dorsal valve slightly concave. Surface of both valves smooth, except sometimes for faint incipient costellae or fine growth lines. Interior surface of valves smooth except for septa. Long median septum in both valves; rather squarish in cross-section and terminating bluntly. Variable number of accessory septa, but the number is stable for each species, and there is the same number in both ventral and dorsal valves. In the ventral valve are strong teeth, but no dental plates. In the dorsal valve are sockets to accommodate the ventral teeth, and with the sockets are socket ridges (or possibly combined socket ridges and crural bases).

Comment. This genus is established to accommodate a group of more than six species of chonetoid brachiopods found in the Lower Devonian rocks of Tasmania and Victoria. Two of these species have already been described as *Anoplia australis* and *Anoplia withersi* (Gill, 1942, 1945, 1950*b*), and in addition to these is the genotype which was previously referred to as *Anoplia* sp. (Gill, 1948*a*, p. 72). The new genus compares with *Anoplia* in its chonetoid outline, small size, smooth exterior surface, and presence of bluntly terminating median septum in both dorsal and ventral valves. On the other hand, it contrasts with *Anoplia* in that the median septa are long, and apparently associated with a long ventral muscle field and not a short one as in *Anoplia*. The median septa are accompanied by accessory septa, and this set-up of septa is one of the most characteristic features of the new genus. The interior of both valves of the genotype is 'strongly pustulose' whereas in *Notanoplia* the interior surfaces are smooth except for the septa. No 'tripartite median process' has been found on the exterior of the dorsal valve as in the genotype, nor any spines as in *A. helderbergiae*. Published figures show ridges in the ventral valve of the genotype that look like dental plates; there are no comparable plates in *Notanoplia*.

Because of its obvious affinities with *Anoplia*, the new genus is named *Notanoplia* (Greek *notos* = south, a reference to its description from Australia, and the generic name *Anoplia*). The two genera are probably isocronons. Stratigraphically the new genus is valuable as an index fossil because it occurs in both arenaceous and argillaceous facies. Also the numerous septa greatly strengthen the shell mechanically, and it is rare to find a broken one. Where currents have not been too strong, it is not uncommon to find both valves still attached to one another, which suggests that this brachiopod possessed strong hingeline ligaments. When *Notanoplia* occurs, it is usually present in large numbers. These last two characters it shares with *Plectodonta bipartita* (Chapman), with which it is frequently associated.

Notanoplia pherista, gen. et sp. nov.

Pl. I, figs 29-32

Type Material. 1. HOLOTYPE consisting of the steinkern of a ventral valve (N.M.V. 14827).

2. PARATYPE consisting of the steinkern (N.M.V. 14828) and external mould (N.M.V. 14827) of a dorsal valve.

Both specimens are preserved in a greyish white siltstone and the impressions of the shells are covered with a film of yellow iron oxide. The locality is no. 16, which is on the right bank of the Little Henty River about one mile S.E. of Zeehan.

Formation. Bell Shale.

Description. HOLOTYPE ventral valve subsemicircular, being 1 cm. wide and 7 mm. long. Hingeline straight, and a little shorter than the greatest width of the shell, making the cardinal angles a little obtuse. Palintrope narrow, but highest in centre and reducing in height towards cardinal extremities. Valve well inflated for this genus, which usually has a very thin body cavity; the median longitudinal profile rises quickly at the umbonal end to 2·5 mm. above the plane joining the valve margins, then descends slowly towards the anterior margin. Short blunt umbo.

Median septum whole length of valve; 0·5 mm. at widest; of somewhat squarish cross-section. It commences at the umbonal end as a fine line 0·5 mm. long, then expands into a flat platform 1·5 mm. long. Such structures are common in strophomenids, and are interpreted as muscle attachments. From this platform

to the anterior margin the septum continues more or less even in size. The accessory septa are approximately one-third of the distance from the hingeline to the median septum. They reach the lateral margins of the valve, but the umbonal termini are not clearly defined. This appears to be characteristic of this species, and is no doubt due to secondary calcification; this sometimes causes the secondary septa to almost disappear. Muscle impressions are difficult to detect, but in the holotype there is a faint excavation of a central flabellate area which reaches most of the length of the valve, if not the entire length. It has been noted (Gill, 1950b) that in chonetids there is a close relationship between the length of the septum and the length of the muscle field. In *Anoplia helderbergiae* the median septum is short and the muscle field likewise short (Schuchert, Swartz, Maynard, and Rowe, 1913, p. 340).

Teeth blunt and short; 2·5 to 3 mm. apart. Associated with them are minute thickenings on the shell wall which might be regarded as either wide teeth bases or incipient dental plates. The external mould of the holotype is not preserved, but the steinkern suggests that the valve was smooth except for traces of radial costellae. Review of a large number of topotype specimens shows that the species was smooth-shelled except for such striae, and sometimes concentric growth lines.

2. PARATYPE dorsal external mould is on the same slab as the holotype, and shows that its surface was smooth except for some fine concentric growth lines. The position of the median septum can be seen, traced by a slight ridge; this is unusual and is due to crushing. However, it suggests that the shell was fairly thin.

The paratype steinkern of the dorsal valve presents a sub-quadrate valve 7 mm. long, and a little over 8 mm. wide, but it has been affected by the shearing the matrix has suffered. Hingeline straight and a little shorter than the greatest width of the valve, thus making the cardinal angles a little obtuse. Palintrope linear, and more or less the same width across the valve. Valve flat in the areas around the cardinal angles but slightly concave in the median area. Short, blunt cardinal process jutting a very short distance beyond the hingeline; there are two faint longitudinal furrows on the process, so that to this extent it may be described as tripartite. The median process is not fused with the process, but commences a little anterior to it. The septum extends the whole length of the shell, and although fairly consistent in strength it is a little higher in the middle; it is somewhat squarish in cross-section. Accessory septa are present, and like those in the ventral valve do not join the median septum or other structure, extend to the lateral margins, and tend to be obliterated by secondary calcification. Here again too they are nearer the hingeline than the median septum, and not as well developed as the median septum. Continuous with the cardinal process are socket ridges, or possibly combined socket ridges and crural bases. These ridges curve anteriorly from the process, then run along almost parallel to the hingeline and close to it. The ridges are fine structures, but begin comparatively thick and gradually thin out terminally.

Comment. *Notanoplia pherista* is the largest and best preserved of the species of this genus at present known, whether described or undescribed, and hence its trivial name (Greek *pheristos* = strongest and best). It is common in the beds from which it comes.

The new species has two accessory septa in each valve like *Notanoplia australis*, but all the septa reach the anterior margin, and there is a tendency for the accessory septa to be obliterated by secondary calcification. *Notanoplia australis* and *N. withersi* have a very thin body cavity, but the new species' inflated ventral

valve with a subplanate dorsal valve provides a body cavity large for this genus. The cardinalia differ in detail from the other described species, and *N. pherista* is the only species in which concentric growth lines have been found.

Associated with the type specimens on the same pieces of rock are *Eospirifer*, *Maoristrophia*, *Trimerus*, and crinoid columnals.

Genus **Protoleptostrophia** Caster, 1939

Protoleptostrophia plateia Gill

Protoleptostrophia plateia Gill, 1948, pp. 64-65, Pl. VIII, figs 29, 45.

Impressions of shells belonging to this species are very common in the Florence Quartzite, including localities 15, 26, 32, 45, 46, 60, 61. (N.M.V. 14833-4). *P. plateia* is so characteristic of this formation that, like *Notoconchidium*, it may be regarded as one of its index fossils. A limitation on precise identification exists in the fact that the prosopon of neither the type specimens nor those from Zeehan can be distinguished satisfactorily because of the coarseness of the enclosing sediments.

The relationships of *P. plateia* to other protoleptostrophids has been discussed in a recent paper (Gill, 1949*c*, pp. 100-103). It seems to the writer also that the form from the Baton River Beds in New Zealand which Shirley (1938, p. 468, Pl. XLI, figs 7-9) named *Leptostrophia explanata*, and Allan (1942, p. 146) renamed *Rhytistrophia shirleyi*, belongs to this gens or group of species. Many wrinkles in specimens examined by the writer are due to crushing, but some weakly developed wrinkles do occur, however, as they do in *P. affinalata* (Gill, 1949*c*). Whether one places the New Zealand species in *Protoleptostrophia* or *Rhytistrophia* depends on how strictly one interprets Caster's (1939) definition of the latter genus as possessing 'strong concentric wrinkles as in *Leptaena*'. However, whichever is the correct generic position, there can be no doubt that the Australian protoleptostrophids are related to the form from the Baton River Beds.

Genus **Maoristrophia** Allan, 1947

Pl. I, fig. 39

Allan established this genus on brachiopods from the Reefton Beds in New Zealand (Allan, 1947). Since then two species have been described from locality 16 at Zeehan, viz., *M. careyi* and *M. banksi*, and another species from Lilydale, Victoria, viz., *M. keblei* (Gill, 1949*a*, 1950*a*). The last named species has now been recognized also in strata near the top of the Mt. Ida Beds in the Heathcote District of Victoria (Thomas, 1937) at locality 54, parish of Redcastle (*vide* maps published by the Mines Dept. of Victoria). The genus has also been noted in a collection in the National Museum, Melbourne, made by the author from the Baton River Beds in New Zealand, and as this is a new record it is figured herein (Pl. I, fig. 39). The specimen is determined as *Maoristrophia neozelanica* Allan, and is registered number 14786 in the National Museum palaeontological collection.

In recent revision of the age of the Reefton Beds, Allan (1947) concluded that they are middle Lower Devonian (Siegenian) in age. The Baton River Beds are generally regarded as being of the same age but a different facies. The beds at Lilydale from which *Maoristrophia* was obtained are believed to be Siegenian in age by the writer, and the overlying Cave Hill limestone to be Coblenzian. The presence of *Maoristrophia* at Zeehan, therefore, suggests that the beds there are likewise Siegenian in age.

Genus **Notoleptaena** Gill, 1950

Notoleptaena sp.

The genotype of *Notoleptaena* is *N. linguifera* from the Heathcote District of Victoria (Gill, 1950c), and a second species, *N. otophera*, was at the same time described from the Killara District of Victoria. The former species is a massive one from a sandy facies, and the latter a more finely built shell from an argillaceous facies. The Tasmanian specimen is comparable with neither of the above species, but it closely resembles an undescribed species from the Kinglake District of Victoria. This third species is more like *N. otophera* than *N. linguifera*, but lacks the alate cardinal angles which characterize it.

Notoleptaena has been collected from locality 1 at Zeehan (N.M.V. 14812).

Genus **Parmorthis** Schuchert and Cooper, 1931

Parmorthis aff. allani (Shirley)

Pl. I, fig. 24

Schizophoria allani Shirley, 1938, pp. 465-466, Pl. XLI, figs 1-3.

The figured specimen (N.M.V. 14836) is from the Bell Shale at locality 16 and closely resembles Shirley's species from the Baton River Beds in New Zealand (Shirley, 1938, Allan, 1945). The cardinalia, muscle arrangements, prosopon, and outline are all closely comparable. The same occurs in the Lilydale District of Victoria.

In the opinion of the writer, Shirley's species belongs to *Parmorthis* and not *Schizophoria*. The latter possesses generally a convexo-concave shell with resupinate lateral profile and a low dorsal fold; the diductor scars of the ventral valve tend to be divergent; the dorsal valve has large and not small cardinalia, the crural apparatus is widely divergent and not compact, and there are characteristic muscle marks and pallial trunks (Schuchert and Cooper, 1932, Cooper in Shimer and Shrock, 1944). In all these ways *Schizophoria* differs from *Parmorthis*.

Genus **Camarotoechia** Hall and Clarke, 1893

Camarotoechia synchoneua, sp. nov.

Pl. I, figs 12-13, 19-20

Type Material. 1. HOLOTYPE represented by the steinkern of a ventral valve preserved in whitish sandstone (leached quartzite) from Smelters' ridge, near Zeehan (loc. 17). N.M.V. 14844.

2. PARATYPE represented by the steinkern of a dorsal valve preserved in the same matrix and from the same locality as the holotype. N.M.V. 14845.

Formation. Crotty Quartzite.

Description. 1. HOLOTYPE ventral valve shallow, transversely ovoid in outline, being a full-grown shell. The younger shells are more rounded, and nearer the proportions of the paratype. Greatest width, which is about the transverse midline of the shell, 3 cm. Length in plan about 2 cm., but length down the midline from the tip of the beak to the centrepoint of the tongue is 2·7 cm. The main part of the valve is flattish, but the deep median sinus extends as a tongue about 8 mm. beyond the rest of the anterior margin. The sinus is 3·5 mm. deep at its deepest part, and 13 mm. wide. Valve strongly costate with about 19 costae, three of which are in the sinus. Anterior commissure strongly uniplicate. Beak

well defined. Well developed dental plates continue forward round the sides of the muscle field as low ridges. The anterior margin of the field is faintly indicated by an incipient ridge. Muscle field spatulate, undivided. The lateral margins of the delthyrium define an angle of the order of 105°.

2. PARATYPE dorsal valve strongly convex, always much deeper than ventral valve. Width 21 mm. in plan, and length 17 mm. in plan, but 24 mm. following the midline profile. Anterior margin strongly uniplicate. Valve costate like the ventral valve; four costae on median fold which corresponds to the sinus of the opposing valve. Strong median septum extending about 1 cm. down the midline. Hingeplate divided, the sides extending anteriorly into crura which show as holes in the steinkern about 4 mm. apart.

Comment. The trivial name is from the Greek *synchoneuo* meaning *to smelt*, being a reminder that the species is described from, and is the dominant fossil in, the fossiliferous band on the crest of the ridge behind the Smelters' works, near Zeehan. Being the only adequately decipherable fossil found so far in the Crotty formation, this fossil is important from a stratigraphical point of view. The formation has been given many different ages in the past, but the presence of a large well-developed *Camarotoechia* means that the strata are either Upper Silurian or younger.

Lamellibranchiata

Genus **Cypricardinia** Hall, 1859

Cypricardinia sp. is present in the Bell Shale at locality 1 (N.M.V. 14802, 14805 counterparts). Chapman (1908) claimed to find *Cypricardinia contexta* (Barrande) in the Lower Devonian of the Lilydale District, Victoria, and Shirley (1938) has recorded the genus from the Lower Devonian of New Zealand.

Arthropoda

Genus **Proetus** Steiniger, 1831

Proetus euryceps (McCoy)

Forbesia euryceps McCoy, 1876, pp. 17-18, Pl. XXII, figs 10, 10*a*.

From grey siltstone at locality 1 in Zeehan have been collected pygidia which cannot be specifically differentiated from those of the above species (N.M.V. 14806, 14811 counterparts). A detailed study has not been made of this trilobite yet, but it is fairly common in the Lower Devonian siltstones of the Kinglake West District, Victoria.

Genus **Trimerus** Green, 1832

Trimerus zeehanensis Gill

Trimerus zeehanensis Gill, 1949*b*, pp. 70-72, Pl. IX, figs 1, 2, 4; text fig. 1D.

Collecting at locality 16 on the bank of the Little Henty River, S.E. of Zeehan, since the species was described, has yielded specimens showing that this trilobite grew larger than the type specimen. For example, a pygidium (N.M.V. 14787, 14788, counterparts) measures 4 cm. long, and a cephalon (N.M.V. 14789-14791, counterparts) measures 3·8 cm. long. Trilobites to which these sections of carapace belonged would be about six inches long.

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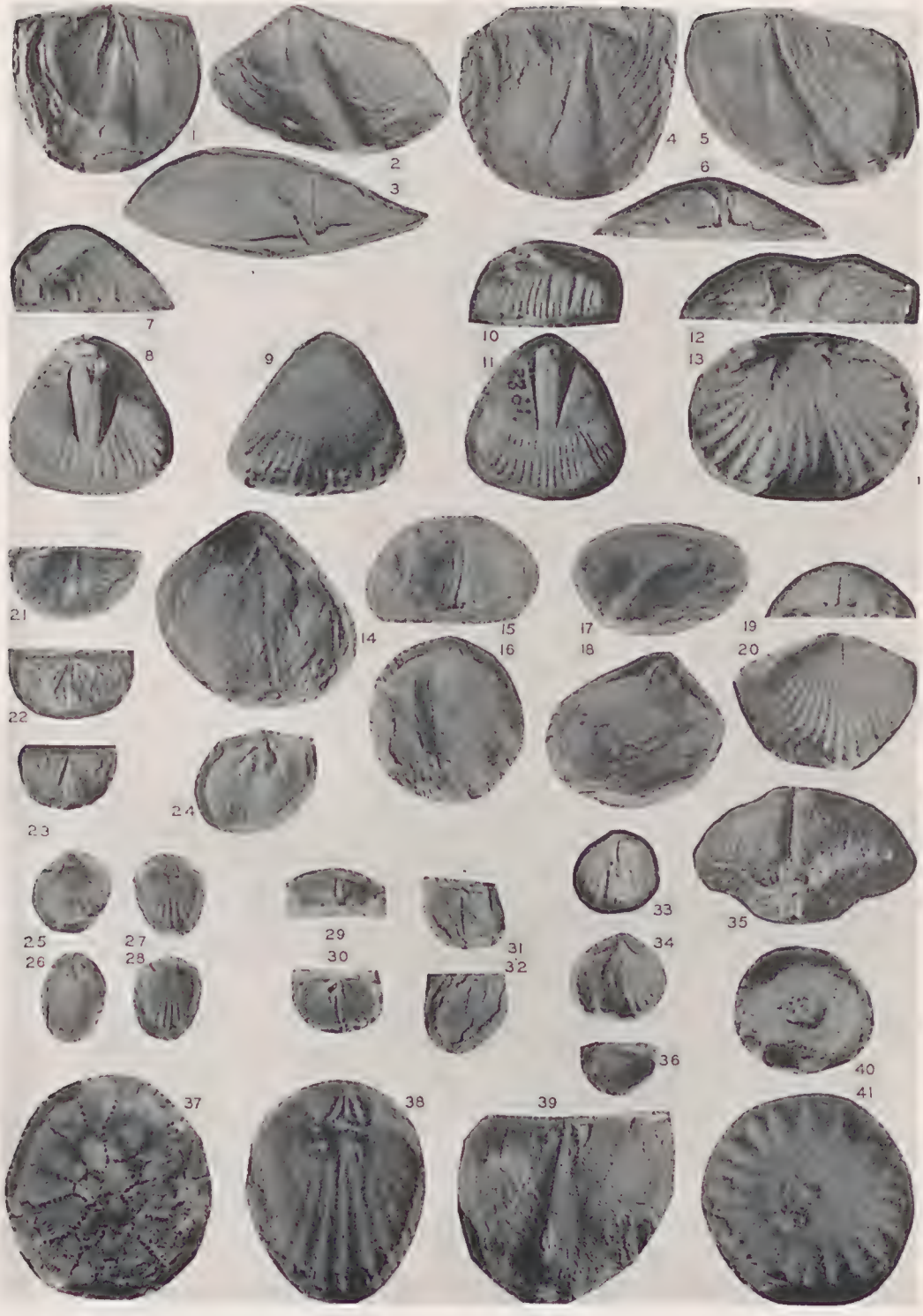
Explanation of Plate I

The photographs are from unretouched negatives, and are natural size unless otherwise indicated. The photography is by Mr. L. A. Baillôt of the Melbourne Technical College.

Fig. 1.—*Eospirifer parahentius*, sp. nov. Steinkern of ventral valve. Holotype.
Fig. 2.—Do. Steinkern of ventral valve. Hypotype.
Fig. 3.—Do. Umbonal view of specimen in fig. 2.
Fig. 4.—Do. External mould of dorsal valve. Paratype.
Fig. 5.—Do. Steinkern of dorsal valve. Paratype.
Fig. 6.—Do. Umbonal view of specimen in fig. 5.
Fig. 7.—*Notoconchidium florencensis*, sp. nov. Oblique view of steinkern of dorsal valve. Holotype.
Fig. 8.—Do. View from above of steinkern of dorsal valve. Holotype.
Fig. 9.—Do. External mould of dorsal valve. Holotype.
Fig. 10.—*Notoconchidium tasmaniensis* (Etheridge). Side view of steinkern of dorsal valve. Lectoholotype.
Fig. 11.—Do. View from above steinkern of dorsal valve. Lectoholotype.
Fig. 12.—*Camarotoechia synchoncua*, sp. nov. Steinkern of ventral valve, umbonal view. Holotype.
Fig. 13.—Do. View from above of steinkern of ventral valve. Holotype.
Fig. 14.—*Meristella bellensis*, sp. nov. Steinkern of ventral valve. Holotype.
Fig. 15.—Do. Steinkern of dorsal valve, umbonal view. Paratype.
Fig. 16.—Do. Steinkern of dorsal valve, view from above. Paratype.
Fig. 17.—Do. Steinkern of ventral valve, umbonal view. Hypotype.
Fig. 18.—Do. Steinkern of ventral valve, view from above. Hypotype.
Fig. 19.—*Camarotoechia synchoneua*, sp. nov. Steinkern of dorsal valve, umbonal view. Paratype.
Fig. 20.—Do. Steinkern of dorsal valve, view from above. Paratype.
Fig. 21.—*Plectodonta bipartita* (Chapman). Steinkern of ventral valve, x 3.
Fig. 22.—Do. Steinkern of dorsal valve, x 3.
Fig. 23.—Do. External mould of dorsal valve, x 3.
Fig. 24.—*Parmorthis* aff. *allani* (Shirley). Steinkern of dorsal valve.
Fig. 25.—*Leptocoelia polyspera* sp. nov. Steinkern of ventral valve. Holotype.
Fig. 26.—Do. Oblique view.
Fig. 27.—*Leptocoelia polyspera*, sp. nov. Steinkern of dorsal valve. Paratype. See also fig. 38.
Fig. 28.—Do. External mould of dorsal valve. Paratype.
Fig. 29.—*Notanoplia pherista*, gen. et sp. nov. Steinkern of ventral valve, umbonal view. Holotype.
Fig. 30.—Do. View from above. Holotype.
Fig. 31.—Do. Steinkern of dorsal valve. Paratype.
Fig. 32.—Do. External mould of dorsal valve.
Fig. 33.—*Eatonia (Eatonia) polynecta*, sp. nov. Dorsal view of steinkern of both valves. Holotype.
Fig. 34.—Do. Steinkern of another ventral valve. Paratype.
Fig. 35.—Do. Umbonal view of steinkern of both valves, x 3. Holotype.
Fig. 36.—*Chonetes* aff. *ruddockensis* Gill. Steinkern of ventral valve.
Fig. 37.—*Pleurodictyum megastomum* Dun.
Fig. 38.—*Leptocoelia polyspera*, sp. nov. Steinkern of paratype dorsal valve, x 3. to show cardinalia and prosopon.
Fig. 39.—*Maoristrophia neozelanica* Allan.
Fig. 40.—Crinoid columnal 1 from Crotty grit.
Fig. 41.—Crinoid columnal 2 from Bell Shale, x 3, to show structure.



Palaeontology of the Eldon Group Formations, Zeehan, Tasmania.

Silurian and Devonian Stratigraphy of the Zeehan Area, Tasmania

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(Read 1st November, 1949)

With 2 Text Figures and 3 Plates

The renewed exploration of the Zeehan Mining Field in Western Tasmania has led to a more detailed study of the geological structure of the area, and the authors have investigated recently the Middle Palaeozoic sequence of sedimentary rocks. After spending a week on the Gordon River studying the 'Gordon River Limestone' (a key formation in West Coast stratigraphy), the limestone and succeeding formations were studied in the Zeehan area.

Photo-Geology

The stratigraphic work described in this paper was based on a geological map of the area prepared from aerial photographs by Professor S. Warren Carey of the University of Tasmania. He recommended that the stratigraphic studies be based on a comparatively undisturbed area south of Zeehan rather than on the very faulted Zeehan area. This suggestion was adopted and the stratigraphic succession was determined, but the extremely rough nature of the country made the work very difficult and placed limitations on the amount of palaeontological material which could be collected. This work was therefore supplemented by the study of railway cutting sections and sections in the cleared country around Zeehan.

Three great advantages accrued from the use of the photo-geological map and the aerial photographs—

1. The map provided beforehand an idea of the structure, thus making simpler the planning and execution of the field work.
2. The country is very rough, and the aerial photographs made it possible to save a great deal of time and physical effort by showing the most suitable routes for traverses.
3. In the past, difficulty has been experienced by field geologists in describing localities in rough country of this kind. References are found in the literature to such temporary features as tracks and blazed trees. However, localities can be pin-pointed from the aerial photographs, and either transferred to a map, or a reference given relative to the centre point of an officially numbered and published photograph. In Tasmania these are supplied by the Department of Lands and Surveys. An index to fossil localities will be found as Appendix B.

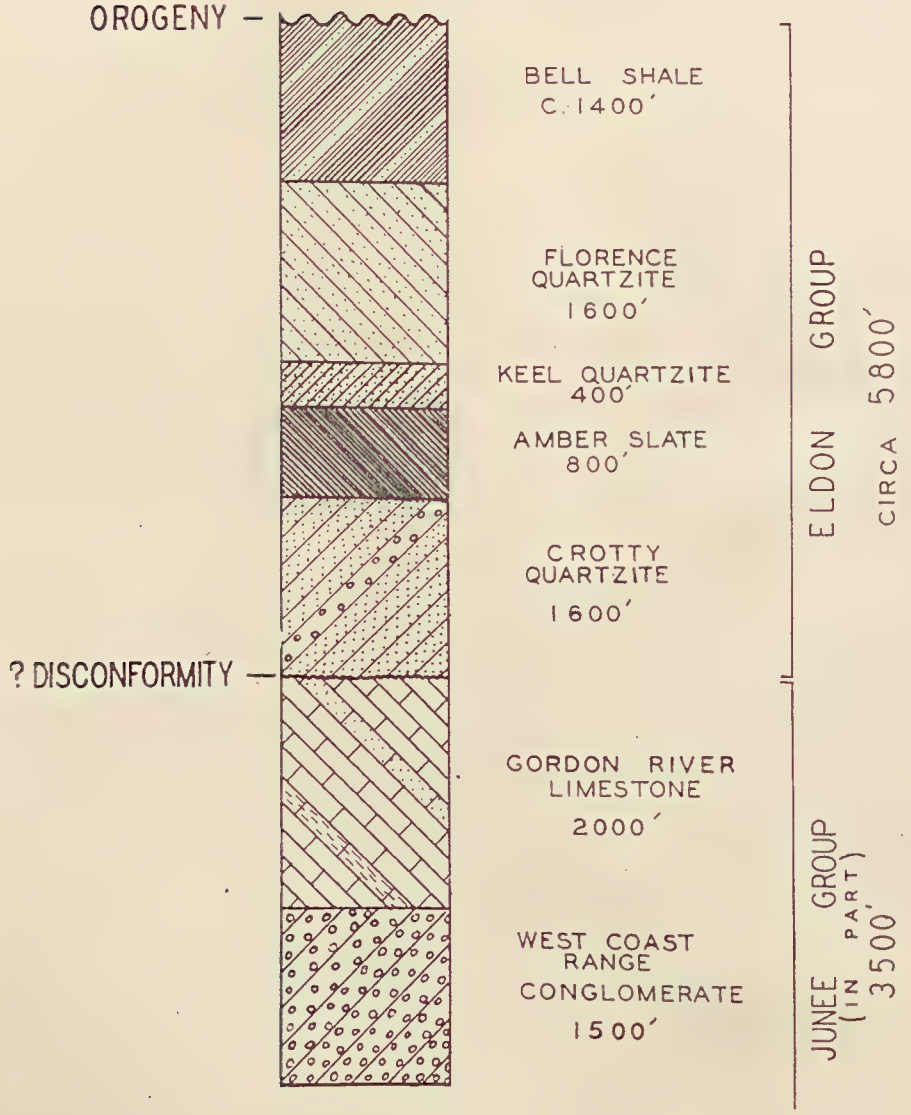

FIG. 1.—Stratigraphy and Diastrophism.

Geological Sequence

The stratigraphical succession is represented in fig. 1. This series of sedimentary rocks on the whole is a highly arenaceous one, even the limestone having sandy horizons. The strata are strongly folded, and regional metamorphism is present as a function of the competence of the beds. An average of eighteen measured dips in the Eden area gave the figure of 50°, and this was used in calculating the thicknesses of the formations. As all the dips are high, this method is not inaccurate. The average dip in the Zeehan area was 70°, this being due to the highly folded nature of that district.

In 1949 Loftus Hills and Carey put forward a tentative classification of the Silurian and Devonian rocks, which is now slightly modified (fig. 2) with their agreement as far as possible, the names already proposed have been retained, and at the same time the new code now being accepted taken into account (Glaessner, *et al.*, 1948). The name 'Drumlin' was dropped because it is the name of a geological feature, and so likely to be confusing. The new names are 'Amber', after the Amber Rivulet which crosses this formation, and 'Florence' after a ridge of that name near Zeehan (see Plates II and III) consisting of rocks of that formation. The type section for all the Eldon Group formations discussed in this paper is in the vicinity of Eden Siding (see State Map 4M) about 10 miles south of Zeehan on the Zeehan-Strahan railway. This area is uninhabited and does not provide sufficient geographical names for formational names. Eden Siding is on the Gordon River Limestone.

Present Classification	*Earlier Classification*
BELL SHALE ± 1400′	BELL SHALES
FLORENCE QUARTZITE 1600′	DRUMLIN SANDSTONES
KEEL QUARTZITE 400′	KEEL FORMATION
AMBER SLATE 800′	
CROTTY QUARTZITE 1600′	CROTTY SANDSTONES

Fig. 2.—Silurian and Devonian Formations.

Junee Group

The West Coast Range Conglomerate and the Gordon River Limestone formations have not yet been formally defined, but this is being done elsewhere and so these are not included in the Eden sequence of definitions.

West Coast Range Conglomerate

This formation constitutes some of the most prominent features of West Tasmanian geomorphology, but at the point of the section it has been planated with the rest of the formations during the development of the Henty Peneplain (Gregory, 1903). The relationship of the conglomerate to the Gordon River Limestone in this area was recognized by Waller in 1904, and was studied by the writers at an abandoned mine (loc. 77) about half a mile SSE. of Greive Siding. The spoil heaps show the presence of—

1. A quartzite which is undoubtedly the uppermost member of the West Coast Range Conglomerate formation, forming passage beds from the conglomerate into the limestone.
2. Re-crystallized limestone of a light bluish colour with some ferruginous staining.
3. Ore containing galena and sphalerite.

In the considerable changes of strike attendant upon the strong pitch of many of the folds in this area, the West Coast Range Conglomerate always remains in the same relationship with the limestone, indicating that the two formations are conformable. This was confirmed by further observations near Zeehan. The thickness of the formation shown in fig. 2 is Loftus Hills' and Carey's estimate for Mt. Zeehan (1949, p. 26).

Gordon River Limestone

In addition to the abovementioned limestone locality, this formation was studied in a ballast quarry (loc. 58) about 50 chains NE. of Greive Siding. Argillaceous and arenaceous impurities were observed in some of the beds, and some appear to contain carbonaceous material. Calcite veins are common, and pyritic inclusions occasional. Certain horizons are considerably leached, while others remain compact. The limestone is often sheared. This locality is stratigraphically low in the formation as it is near the base of the scarp formed by the West Coast Range Conglomerate formation. The limestone has a characteristic physiographic expression as a lowland, and judging by this criterion it has a thickness of the order of 2000 feet. Outcrops are difficult to obtain, but the proving of limestone at the two localities mentioned shows that its lower extent is approximately coincident with the eastern wall of the valley, and no reason suggests itself why the western wall of the valley should not likewise mark the upper extent of the limestone.

Fossils were obtained from this formation at loc. 58, but preservation was generally poor. The fossils, which were far from numerous, included tabulate corals, trepostomatous and cryptostomatous bryozoans, with very poorly preserved brachiopods and pelecypods and some well preserved ostracods. The genera identified are set out below—

Coelenterata: *Favosites.*
Polyzoa: *Rhinidictya.*
Polypora.

The trepostomatous types found were difficult to identify and work is proceeding on these. The brachiopods included a strophomenid and a rhynchonellid, but insufficient details were preserved to warrant identification. *Rhinidictya* is

found at Zeehan in association with *Tetradium tasmaniense* Chapman and other fossils of Upper Ordovician age and its occurrence at Eden suggests a similar age for the limestone there. If this is true, the base of the limestone at Eden would be high in the Ordovician. More work is needed before the point can be finally resolved.

Eldon Group

The formations of this Group in the Zeehan area in order are the Crotty Quartzite (lowest), the Amber Slate, the Keel Quartzite, the Florence Quartzite, and the Bell Shale (highest). (See figs 1 and 2.) These lithological units are now formally defined and described. The quartzites are of impure types.

Crotty Quartzite

The Crotty Quartzite is hereby defined as a formation of some 1600 feet of quartzitic sedimentary rocks as mapped in Plate III, underlain conformably by the Gordon River Limestone and overlain conformably by the Amber Slate. The formation consists mostly of quartzites, but includes a thick band of quartzitic grit which in places becomes a fine conglomerate. The Crotty Quartzite is usually of a light greyish colour which weathers white at the surface. In places it has a pinkish hue which is not altogether lost on weathering and is characteristic of the lithology of the formation. The rocks are sometimes sheared, and thin milky veins are frequent. Cross-bedding is common.

This formation is a typically unfossiliferous one. Near Eden Siding poorly preserved brachiopods, lamellibranchs, crinoid stems, and tubicolar structures were recognized, but even generic determinations were difficult. As the matrix preserves so little detail, it is easy to confuse various types of tube-like structures, and the following generalisations have proved useful in the field:—

1. Tube structures at right angles to the bedding planes, straight, and unbranching are generally the tubes of marine worms. These are discussed in an accompanying palaeontological paper (Gill, 1950).
2. Tube structures parallel to the bedding planes, sometimes straight and sometimes curved, but unbranching, are generally pieces of crinoid stem. Sometimes there is enough structure preserved to make out the columnals.
3. Tube structures which are branched. These are usually polyzoa.

From experience so far it would appear that the tubicolar quartzite in the West Coast Range Conglomerate is usually (if not always) of the first type, whereas in the Crotty Quartzite all three types are present. As these two formations are so sparsely fossiliferous, such distinctions are helpful in field work. The West Coast Range Conglomerate, being older than the Ordovician Gordon River Limestone, is probably too old to have either crinoids or polyzoa.

The Crotty Quartzite constitutes the ridge at Zeehan on which the Smelters' works are built. As the ridge is bare, and is excavated in places, it provides an excellent opportunity for studying a cross-section of the formation. The majority of the strata yielded no fossils, but one highly fossiliferous band (loc. 17) was found occurring along the crest of the ridge under the median grit, and at the Smelters' sand quarry (loc. 19) large and distinctive crinoid columnals were noted. Similar columnals were noted at loc. 3. The quartzites on top of the Smelters' ridge have been strongly leached, and in some places so de-silicified as to permit of the rock being readily broken down for sand. There is a similar quarry at the south end of Manganese Hill in Crotty Quartzite.

The coarse grit band characteristic of this formation can be clearly seen on the Smelters' ridge, most of it being of remarkably open texture. The examination of fresh rock from a deep railway cutting near the 22-mile post and from mine workings, and of mineralised rock as at the Central Balstrup Mine, indicates that the grit and conglomerate contain pebbles of many different kinds of rocks and minerals, and the open texture of the leached horizons is due to the removal thence of clay, silt (siltstone pebbles were noted in the fresh rock), and soluble minerals. Mr. J. J. Jenkin of the National Museum, Melbourne, tested the percentage by volume of insoluble matter in rocks from various horizons. Fresh Crotty Quartzite from the deep railway cutting at loc. 49 showed 88 per cent insoluble matter, while specimens of the leached rock from Smelters' ridge were practically 100 per cent insoluble matter. The high rainfall of this area (90-100 inches) causes strong leaching of the surface rocks. Another lithological feature of importance is that the rocks are mixedstones, i.e., consisting of both roundstones and sharpstones, which is characteristic of rapidly eroded sediments in a geosynclinal trough.

Other results of interest from Mr. Jenkin's tests are that the sample of rock from beside the Central Balstrup Mine contained 0·57 per cent of heavy minerals, a sample of Florence Quartzite from loc. 15 contained 94 per cent insoluble matter, a sample of Amber Slate from loc. 42, 93·5 per cent, and a sample of Bell Shale from loc. 16 had 82·4 per cent.

Waterhouse (1916) described some rather unfossiliferous rocks from near Trial Harbour, on the coast west of Zeehan, in the following terms: 'The rocks are invariably very siliceous sedimentaries, white in colour, the predominating members being sandstones and grits, although sometimes coarser pebbles occur, giving the rock more the features of a conglomerate. Although hard and usually silicified, there appears to have been no crushing of the sediments. Individual particles vary in shape from angular to rounded. It is worthy of note that in many of the finer sandstones, as well as in the coarser grits, although the bulk of the rock is made up of glassy quartz, there are softer fragments which show signs of kaolinisation.

'The striking feature of the rocks is the occurrence of abundant cavities, many of which are strongly suggestive of fossil impressions, although no definite fossils were found. Some of the cavities are quite irregular in shape, and are doubtless caused by the weathering out of some of the softer constituents of the rock; others are approximately circular in plan, but of small thickness, while others again suggest the forms of brachiopods, although the impressions are not sharp. Some of the cavities are circular or slightly oval in shape, but one-quarter of an inch in diameter, and have a small circular central pillar, i.e., the cavities are cylindrical. These cavities are very suggestive of crinoid stems. Although they do not appear to be common, one loose fragment of white sandstone was obtained which showed on weathered surfaces some irregular tubular casts up to about one inch in length all lying parallel with the bedding plane of the specimen. In general form they resemble the so-called "pipe-stems' of the tubicolar sandstone which is associated with (and later than) the West Coast Range Conglomerate in various localities on the West Coast. These casts, however, are rather more indefinite than typical "pipe-stems", and lie horizontally, and not perpendicularly, with reference to the bedding planes.' The above description fits the Crotty Quartzite precisely, both in lithology and content. The cavities with the central pillar are clearly crinoid columnals. The one inch tubular casts are probably coprolitic, and are reminiscent of some found *non in situ* east of Johnston's Flat, near Zeehan, by Mr. Bruce Webb.

Amber Slate

The Amber Slate is hereby defined as a formation consisting of some 800 feet of grey slates (see Plate III), underlain conformably by the Crotty Quartzite and overlain conformably by the Keel Quartzite. There is much fine silica in these slates, which shows that they were siltstones before their regional metamorphism rather than claystones. The slates are generally highly fissile, and on weathering turn to a yellowish-brown, sometimes with pinkish and purplish hues. The formation is very uniform in its lithology.

North of Greive Siding, at the 22-mile post, the railway passes from the Gordon River Limestone of the valley into a high cutting which traverses Crotty Quartzite. Fossils were found at 460 feet and 1157 feet north of the 22-mile post. The railway then passes through Amber Slate, following this formation for about 1½ miles. Four fossil localities were discovered (locs. 38, 41, 42, 47), and at the first three of these the true dip was obtained from the lay of the fossiliferous material, viz., 57° N., 25° N., and 32° N. respectively. This shows that the beds, although now in the form of slate, are actually conformable with the underlying Crotty Quartzite.

Keel Quartzite

The Keel Quartzite is hereby defined as a formation consisting of some 400 feet of quartzite as mapped in Plate III. This formation is conformably underlain by the Amber Slate and conformably overlain by the Florence Quartzite. The rock is a grey quartzite, and quite bluish when fresh. It weathers like the other quartzites to a whitish colour.

In the railway section north of Greive Siding already partly described, Keel Quartzite was noted above the Amber Slate. Well-defined ripple marks were observed in one bed. In the railway section somewhat shaley quartzites occur at the top of the formation, and this accounts for the valley between the Keel hogbacks and the Florence ridges.

The Keel Quartzite is very poorly fossiliferous.

Florence Quartzite

The Florence Quartzite is hereby defined as a formation consisting of some 1600 feet of quartzite as mapped in Plate III. It is conformably underlain by the Keel Quartzite, and conformably overlain by the Bell Shale. The quartzite is usually light grey in colour, but not infrequently stained yellowish-brown with iron oxide. Like the other quartzites, it weathers to a whitish rock except that there is still often some of the iron stain left. This is the only formation in the Eldon Group in this area containing any quantity of iron stain, and this fact was found useful as accessory evidence in the field.

The strata of this formation are highly fossiliferous, so much so that the rock must have been a calcareous sandstone originally, and even a sandy limestone in places. All the calcareous matter is now leached away, so that the fossils are preserved in the form of casts and moulds. An enormous amount of calcium compounds must have been carried away by vadose waters.

It is to be noted that both the Florence Quartzite and the contiguous Keel Quartzite are arenite formations, but each has a very distinctive physiographic expression. The Keel Quartzite forms hogbacks—sharp, keel-like ridges—and hence the name of the Ridge from which the formation takes its name. The upper beds of this formation are physiographically weaker, so that a valley is always

formed in them, thus separating the two quartzite formations. The Florence Quartzite forms rounded ridges across which branch streams cut back, with the result that a number of drumlin-shaped eminences are formed, and hence the name originally given to this formation.

Bell Shale

The Bell Shale is hereby defined as a formation of the order of 1400 feet of siltstones, commonly with shaley fracture, and with interbedded quartzitic bands. The formation is conformably underlain by the Florence Quartzite, but is terminated above by a regional unconformity brought about by the Middle Devonian orogeny. This diastrophism is responsible for the folding and emergence of the formations described in this paper, and apparently also for the injection of the metalliferous lodes which caused mining at Zeehan to be undertaken. In the present state of our knowledge, there appears to be more diversity of lithology and faunal assemblages in the Bell Shale than in any of the other Eldon Group formations. This is probably connected with the movements which brought sedimentation to a close in this part of the Tasman Geosyncline. A hint has been given of a possible higher formation than the Bell Shale (L. Hills and Carey, 1949, p. 28) having a thickness of 'at least 3000 feet', but the field work just completed has proved that there are no beds in the type area younger than the Bell Shale.

There is considerable variation in the amount of regional metamorphism in the strata of this formation in the faulted Zeehan area, where slates occur in the proximity of large faults. In such localities the sandstones are strongly sheared, and the quartzite bands are buckled and broken. Some of the quartzitic horizons are very finely banded due not to laminated bedding but alternate fine layers of lighter and darker sediment. This feature has not been seen in any other formation of the Eldon Group.

Appendix A provides a table for the ready recognition in the field of the Eldon Group formations described above.

Permian System

Rocks of this system outcrop in railway cuttings and on the prominent hills on either side of the railway line on the Strahan side of Eden. They are faulted against formations of the Junee and Eldon Groups. The Permian rocks with their possibility of coal have received some attention from geologists in the past. Voisey (1938, p. 322) mentions them but was simply recording passages from Johnston (1891) who was the last geologist to make ground observations on them. The area occupied by the Permian was delineated by Carey in his photo-geological map. Insufficient time was available to make the definition of formations possible, and so the following are notes on outcrops studied.

At Firewood Siding (loc. 72), brown to grey micaceous sandstones outcrop. The sandstone is finely bedded, of medium grainsize and extremely micaceous, the mica being of a clear variety. Plant fragments, although present, are not common, but carbonaceous laminae are well developed, particularly in finer grained sandstones. Current bedding is present in these finer sandstones, and all are jointed, the jointing dipping to the east.

In the creek bed to the north-east of the siding (loc. 71), a grey grit is found, and this contains medium-grained fragments of quartz and argillaceous material with a few fragments of plants up to one-quarter of an inch long, surrounded by iron staining, especially in the weathered zone. White mica is again present.

A prominent homoclinal ridge can be seen further to the north-east of the siding (loc. 70), and this proved to be due to a bed of white conglomeratic grit dipping 230° at 35°. This rock, like those already described, has an argillaceous cement. It is of a glistening white colour, and is composed of poorly rounded quartz pebbles up to 5 cms. in diameter in a matrix of smaller sub-angular quartz and occasional argillaceous fragments, again with fine-grained clear micas. There is a rough alternation of pebbly and non-pebbly bands. Current bedding is very common, and in the main dips to the south but not invariably so. No fossils were found.

In the railway cuttings (locs. 73, 74, 75, 76) to the east of Firewood Siding, the main rock type is a fluvio-glacial siltstone with angular, rounded, and facetted pebbles of many rock types in a fine-grained brown matrix. The latter consists of argillaceous material with, however, an appreciable amount of quartz and occasional very fine grains of mica. The pebbles occur in irregular bands and lenses, and close to the top of the siltstone carbonaceous bands become common. The pebbles include quartz (especially near the top of the siltstone), quartzite, schists, and grey granite, one boulder of which was eight inches in diameter and markedly facetted. Fossils were found in two localities in this rock, and are sufficient to establish its Permian age, viz.—

Locality 75:

Brachiopoda	*Martiniopsis oviformis* McCoy.
	Spirifer duodecimcostata McCoy.

Locality 76:

Polyzoa	*Fenestrellina* spp.
	Polypora sp.
	Stenopora sp.
Brachiopoda	*Martiniopsis subradiata* Sowerby.
Mollusca	*Merismopteria macroptera* (Morris).
	Platyschisma oculus Sowerby.
	Conularia inornata Dana.

The matrix at loc. 76 is the rock type described above, while that at loc. 75 is much fresher and of greenish grey colour. Preservation is such that specific identification of the bryozoa was precluded.

Correlation of these strata with other Permian sequences in Tasmania is difficult. They are somewhat different from most other Permian rock types in the possession of abundant mica flakes, although these are recorded from Prider's Bronte Facies of the Marlborough Series (Prider, 1947, p. 133). The fossils are not of very great value for correlation. One of us (M.R.B.) has noticed, however, that the molluscs recorded from this locality are more common in the lower formations in the Hobart area than they are in the higher ones. These strata may be equivalent to the Granton Formation of Eastern Tasmania, but the evidence is not yet sufficient for definite correlations.

Structure and Diastrophism

The Eldon Group strata of the Zeehan area are strongly folded, with considerable pitching, by compressive forces operating in a S.W.-N.E. direction. In the comparatively undisturbed area south of Zeehan, the folds pitch to the north-west, and this strong pitching gives the beds a very sinuous outcrop (see Plate I). The bedrock is traversed by many faults of different types and amount of throw. The faulting of this area has been considered to be connected with the Middle

Devonian diastrophic and metallogenetic period (e.g., Twelvetrees and Ward, 1910, Ward, 1911, L. Hills, 1921), the ores being regarded as differentiates from the Heemskirk granite massif. However, it should be noted that—

1. The fault affecting the Permian rocks in the south of the area is definitely of later age, and
2. L. Hills and Carey (1949, p. 38) state that it is possible that the Heemskirk granite is of Lower Carboniferous age.

It would appear that there are fault systems of various ages. *A. priori* one would expect faults to be associated with the original epi-Eldon folding, with the intrusion of the doleritic sills (Edwards, 1942), and with the Tertiary faulting held responsible for some of the massive grabens of Tasmania.

We wish to record our indebtedness to Professor Carey for suggesting this area to us as one worthy of attention and to him and North Broken Hill Pty. Ltd. for making available to us their maps and aerial photographs of the area studied. These facilitated the work considerably. Help in the area was made available through the courtesy of Dr. M. D. Garretty, and Mr. B. P. Webb, B.Sc. assisted us in the field and helped us to check in the immediate vicinity of Zeehan the criteria we had established near Eden. Mr. Ramsay Ford was a willing worker with us at all times during our visit, and lightened the burden of fossils for us on many occasions. Assistance in compilation and drafting was given by Mr. Bruce Ellis.

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Appendix A

Table for Recognition of Formations in the Field

Types of Evidence	*Crotty Quartzite*	*Amber Slate*	*Keel Quartzite*	*Florence Quartzite*	*Bell Shale*
Lithology (*a*) Fresh rock	Light-grey and sometimes pinkish quartzite with mixed-stone grit to fine conglomerate of mixed rock and mineral types	Grey slates	Bluish, light-grey, and dark-grey quartzite	Light-grey and yellowish-brown quartzite	Light- or dark-grey, yellowish-brown to reddish siltstones with quartzitic horizons, some finely banded
(*b*) Weathered rock	Whitish and sometimes pinkish porous quartzite to freestone	Yellowish-brown slates sometimes with pinkish or purplish hues	Whitish porous quartzite	Whitish or sometimes yellowish-brown porous quartzite	Little alteration on weathering
(*c*) Metamorphism	Sheared in places	Fissile slates Fossils across cleavage	Sheared in places	Sheared in places	Shales become slates in major fault zones Quartzitic bands sheared, buckled, or shattered
Physiography	Rounded ridges	Low relief Tendency to dendritic stream pattern	Sharp keel-like ridges (Hogbacks)	Rounded ridges	Low relief with quartzitic bands standing out as low ridges
Palaeontology (*a*) Index fossils and assemblages	*Camarotoechia synchoneua* Gill Annelid tubes Large, flat crinoid columnals with rounded sides	*?Rhenorensselaria* Ostracod zones Slender crinoid columns	No fossils yet specifically associated with this formation. Its physiographic expression is its chief characteristic	*Notoconchidium florencensis* Gill *Eatonia pleonecta* Gill Large actinopterid Masses of crinoid columnals c. ¼" diam. *Maoristrophia-Protoleptostrophia plateia* association	*Chonetes ruddockensis* Gill *Eospirifer parahentius* Gill *Leptocoelia polyspera* Gill *Meristella bellensis* Gill *Notanoplia pherista* Gill *Plectodonta bipartita* (Chapman) *Proetus euryceps* (McCoy) Crinoid columnals with scalloped margins Land plants
(*b*) Relative abundance of fossils	Poorly fossiliferous	Sparsely fossiliferous	Poorly fossiliferous	Richly fossiliferous	Richly fossiliferous

Appendix B

Index to Fossil Localities

Loc.	*Run*	*Photo*	*Dist.*	*Bearing*	*Co-ordinates*		*Notes*
			cms.		*N.*	*E.*	
1	5	21646	9·9	58	5,050	1,730	Quarry on N. bank of creek
2	,,	21644	9·3	108½	5,070	1,039	Garage quarry, Zeehan
3	,,	,,	8·4	104½	4,970	900	Quarry N. W. of hospital
4	,,	,,	9·35	118	4,980	1,270	E. side of Rotunda Hill
5	,,	21646	5·6	52	4,360	2,005	Right bank of creek, 10 yds. E. of road
6	,,	,,	6·85	29	4,210	1,557	Cutting W. side of Oceana Rd., 3 chs. S. of Main St.
7	,,	21644	1·8	73	3,950	381	Johnston's Flat
8	,,	,,	1·4	94	3,860	510	Adit on E. side of Johnston's Flat
9	,,	,,	3·5	165½	3,760	1,010	Ballast quarry on Comstock Railway
10	,,	21646	4·9	339½	3,400	1,770	Old quarry on W. side of road
11	,,	,,	5·05	336	3,340	1,790	About 415 yds. N. of Silver Bell Turn-off
12	,,	,,	5·06	335	3,270	1,770	About 408 yds. N. of Silver Bell Turn-off
13	,,	,,	5·56	323	3,030	1,790	About 258 yds. N. of Silver Bell Turn-off
14	,,	,,	6·15	316½	2,880	1,750	About 100 yds. N. of Silver Bell Turn-off
15	,,	,,	6·55	303	2,650	1,900	Silver Bell Railway Cutting
16	,,	,,	5·5	257½	2,650	2,690	Rt. bank Little Henty River
17	4	21605	9·26	125½	2,035	2,200	30 chs. N.N.W. of Smelters' Transformer Station
18	,,	,,	9·4	129	1,938	2,330	S. slope of gully
19	,,	,,	9·2	140½	1,720	2,520	Smelters' sandy quarry
20					1,806	2,700	Smelters' Railway cutting
21					1,440	3,425	Sth. bank of creeklet on flats
22					1,575	3,640	Crest of low ridge
23					1,640	3,800	Eastern side of crest of high ridge
24	3	21562	8·34	341	—2,465	1,261	On 'bridge' between ridges
25	,,	,,	7·6	335	—2,545	1,417	In small saddle
26	2	21533	11·3	98½	—2,908	787	Near top of ridge
27	,,	,,	9·8	77	—3,065	121	On spur
28	,,	,,	9·15	76½	—3,190	138	Top of ridge
29	,,	,,	8·85	78½	—3,210	173	Cliff on N. side large pool
30	,,	,,	9·3	85	—3,160	55	In whitish quartzite
31	,,	,,	8·6	77½	—3,260	147	Slope of small spur at junction of creeks
32	,,	,,	8·8	80½	—3,260	216	On sharp edge of end of spur
33	,,	,,	6·5	83½	—3,635	329	N. bank of small gully
34	,,	21530	9·7	56½	—3,705	2,665	Near bottom of gully
35	3	21562	10·25	234	—3,530	3,590	11 yds. N. of 36
36	,,	,,	10·30	235	—3,560	3,550	About 3 chs. N. of 37
37	,,	,,	10·95	241½	—3,780	3,415	Railway cutting in Keel hogback
38	2	21530	6·95	38	—4,350	2,565	4 chs. N. of 23-mile post
39	,,	21533	1·45	35	—4,590	156	Bed of small gully
40	,,	,,	1·2	30	—4,620	199	Quartzitic band across small creek
41	,,	21530	8·9	23½	—4,400	2,075	1,490 yds. from S. end cutting
42	,,	,,	8·05	30	—4,350	2,300	Near 23-mile post
43	,,	21533	2·7	335	—4,890	—69	Half-way up gully wall with N. aspect
44	,,	,,	2·35	331½	—4,890	—9	Valley wall with N. aspect

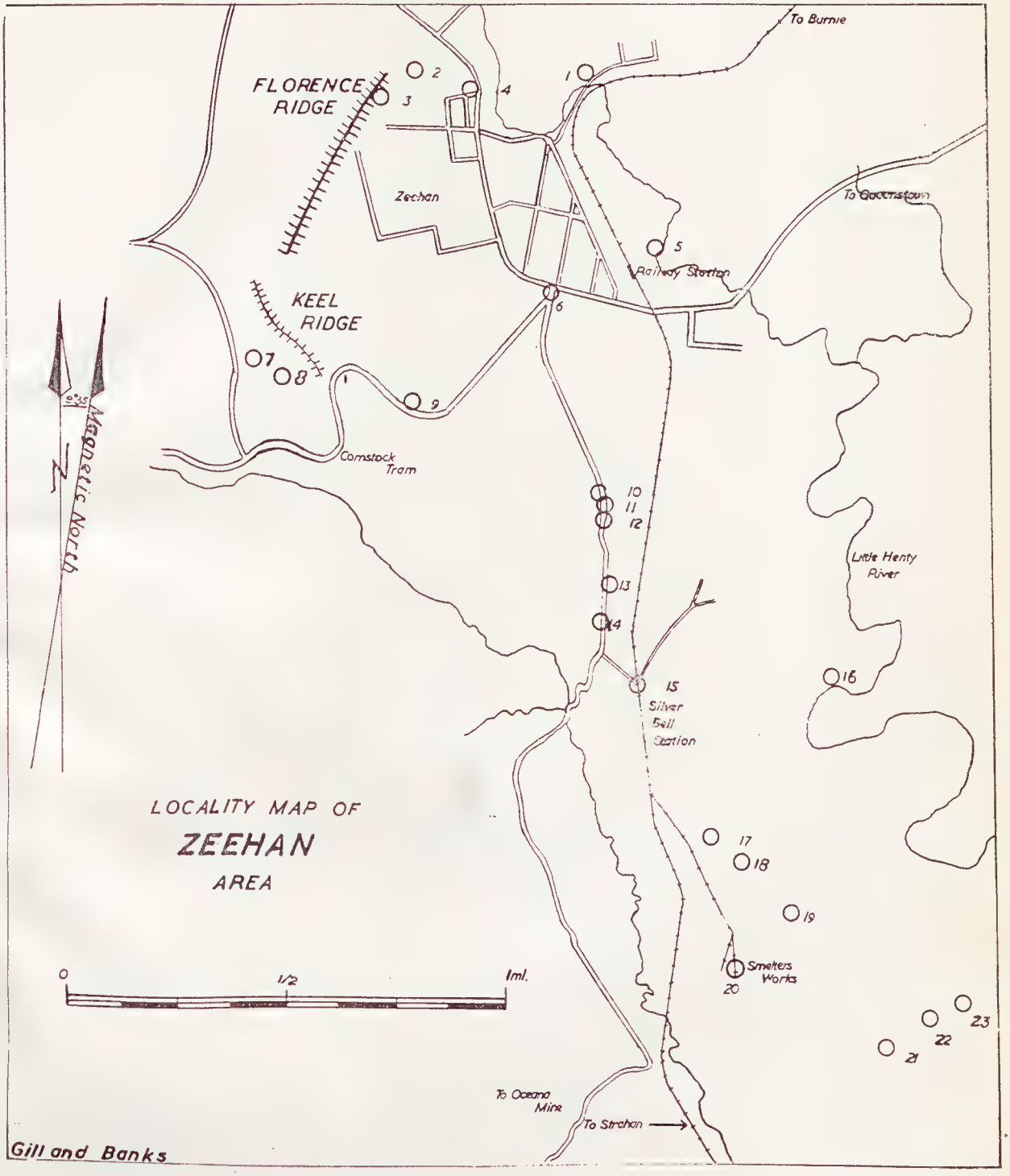
Loc.	*Run*	*Photo*	*Dist.*	*Bearing*	*Co-ordinates*		*Notes*
			cms.		*N.*	*E.*	
45	2	21533	1·95	334½	—4,850	432	Floor of small gully, hard band across creek
46	,,	,,	2·3	292½	—5,070	173	E. of 43 and lower
47	,,	21530	6·45	356½	—5,090	2,110	640 yds. from S. end cutting
48	,,	,,	6·35	340½	—5,370	2,355	370 yds. from S. end cutting
49	,,	,,	5·55	334½	—5,450	2,510	130 yds. from S. end cutting
50	,,	,,	5·1	328	—5,510	2,640	High railway cutting
51	,,	21533	8·2	306½	—5,730	—554	Tree stump on top of ridge
52	,,	,,	8·4	305½	—5,770	—554	Rock from tree stump
53	,,	,,	8·55	305	—5,800	—565	N. side of gully
54	1	23436	12·45	129½	—5,800	—510	Three-quarter-way up ridge
55	2	21530	4·65	266	—5,920	3,395	Railway cutting at bend
56	1	23436	10·35	34½	—6,240	—606	Crest of Keel hogback
57	,,	23432	7·15	57	—6,460	1,563	Floor of small creek on peneplain
58	2	21530	9·1	246½	—6,580	3,890	Quarry in limestone
59	1	23436	7·0	119	—6,560	—1,218	Top of ridge where tree uprooted
60	,,	,,	5·65	103½	—6,680	—1,546	Top of ridge where tree uprooted
61	,,	,,	3·6	117	—7,050	—1,460	On old tramway
62	,,	,,	5·8	144	—6,940	—1,060	Top of ridge
63	,,	23432	4·1	108½	—6,850	2,456	East bank of creek
64	,,	,,	4·15	120	—6,900	2,598	Head of branch creek
65	,,	,,	4·8	159½	—7,160	2,940	Top of another ridge
66	,,	,,	4·95	157½	—7,210	2,950	Top of small ridge on peneplain
67	,,	,,	5·2	160½	—7,260	3,000	Top of hill, Henty peneplain surface
68	,,	,,	5·4	166	—7,305	3,070	150 ft. further uphill from 69
69	,,	,,	5·4	170	—7,360	3,055	On hillside overlooking limestone valley
70	,,	23436	2·75	356½	—7,650	—2,105	On top of homocline
71	,,	,,	2·90	330½	—7,850	—2,040	In creek bed N.E. 72
72	,,	,,	3·70	325	—7,950	—2,120	Firewood Siding
73	,,	,,	1·4	251	—7,800	—1,580	Railway cutting
74	,,	,,	2·7	230½	—7,900	—1,295	Railway cutting
75	,,	,,	3·8	226	—8,000	—1,132	Railway cutting
76	,,	,,	5·35	223	—8,100	—908	Railway cutting
77	,,	23431	5·3	242	—8,150	3,745	Ballast quarry and mine workings

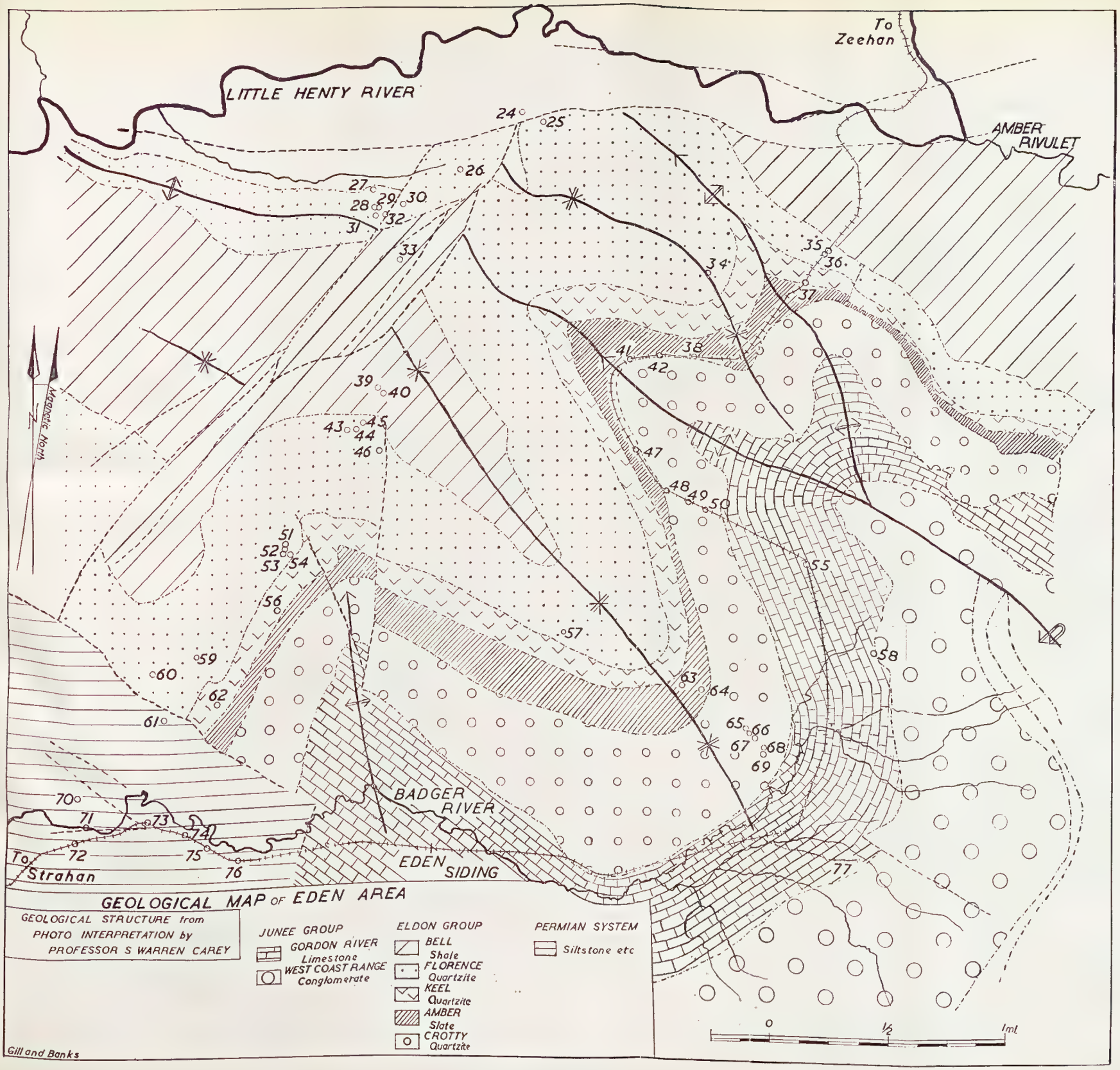
'Loc.' is locality number shown on Plates II and III.
'Run' refers to aerial survey photo runs. All runs are in the Zeehan Quadrangle.
'Distance' is measured from centre of photo quoted.
'Bearing' is taken from line joining the centre of the photo quoted and the next photo west and is measured in a clockwise sense.
'Co-ordinates' refer to Mt. Zeehan and North and East are taken as the positive directions and are measured in yards.

PLATE I

Two aerial photographs of Zeehan Run 1, nos. 23431 (top), 23432 (bottom), to show the structure near Eden. Arranged for stereoscopy; and published by courtesy of the Lands and Surveys Department, Hobart.

(NOTE.—The top of the page is east.)


To Burnie
FLORENCE RIDGE
Zeehan
To Queenstown
Railway Station
KEEL RIDGE
Comstock Tram
Magnetic North
Little Henty River
Silver Bell Section
Smelters Works
To Oceana Mine
To Strahan
LOCALITY MAP OF
ZEEHAN
AREA
0
1/2
1ml.
Gill and Banks


To Zeehan
LITTLE HENTY RIVER
AMBER RIVULET
Magnetic North
BADGER RIVER
EDEN SIDING
To Strahan
GEOLOGICAL MAP OF EDEN AREA
GEOLOGICAL STRUCTURE from PHOTO INTERPRETATION by PROFESSOR S WARREN CAREY
JUNEE GROUP
GORDON RIVER Limestone
WEST COAST RANGE Conglomerate
ELDON GROUP
BELL Shale
FLORENCE Quartzite
KEEL Quartzite
AMBER Slate
CROTTY Quartzite
PERMIAN SYSTEM
Siltstone etc
0 ½ 1ml
Gill and Banks

The Royal Society of Tasmania
1949

Patron:
His Majesty the King.

President:
His Excellency Admiral Sir Hugh Binney, K.C.B., D.S.O.

Vice-Presidents:
W. L. Crowther, D.S.O., M.B., F.R.A.C.P., 1949.
A. L. Meston, M.A., 1949, 1950.

Council:
W. H. Hudspeth, B.A., 1949, 1950, 1951.
F. C. Wolfhagen, LL.B., 1949, 1950, 1951.
J. W. C. Wyett, B.Sc., A.A.C.I., 1949, 1950.
D. Martin, M.Sc., 1949, 1950.
S. W. Carey, D.Sc., 1949.
L. W. Miller, M.Agr.Sc., F.R.E.S., 1949.

Hon. Secretary and Librarian:
Joseph Pearson, D.Sc. (Manchester), D.Sc. (Liverpool), F.R.S.E., F.L.S.

Assistant Hon. Secretary:
D. Martin, M.Sc.

Hon. Treasurer:
S. Angel.

Hon. Auditor:
H. J. Exley, M.A.

Hon. Editors of the Papers and Proceedings:
Joseph Pearson and D. Martin.

Standing Committee:
W. L. Crowther, S. W. Carey, W. H. Hudspeth, J. Pearson.

Annual Report, 1949

The Annual Meeting was held in the Society's Room, Tasmanian Museum and Art Gallery, on the 15th March, 1949.

His Excellency the Governor, President of the Society, presided.

The following Office-bearers were elected:—

Vice-President: Under the Society's Rules Mr. W. H. Hudspeth retired from the office of Vice-President and Mr. A. L. Meston was appointed in his place (retiring 1951).

Hon. Secretary and Librarian: Dr. Joseph Pearson.

Hon. Assistant Secretary: Mr. D. C. Pearse.

Hon. Treasurer: Mr. S. Angel.

Hon. Auditor: Mr. H. J. Exley.

Council: Under Rule 21 Professor V. V. Hickman and Mr. J. Somerville retired as members of the Council and Mr. W. H. Hudspeth and Mr. F. C. Wolfhagen were elected in their place for a period of three years.

Mr. D. Martin was elected for the remaining two years of Mr. A. L. Meston's period of office, as Mr. Meston was appointed a Vice-President.

The names of the full Council for 1949 are given on the previous page.

The Council made the following appointments at its first meeting:—

Assistant Librarian: Miss B. Veale.

Standing Committee: Dr. W. L. Crowther, Professor S. W. Carey, Mr. W. H. Hudspeth and the Hon. Secretary.

The Council elected the following two members of the Society to serve on the Board of Trustees of the Tasmanian Museum and Botanical Gardens:—Mr. W. H. Hudspeth and Mr. F. H. Foster.

Meetings

Nine ordinary meetings were held during the year. At the conclusion of the March meeting a conversazione was held in order to give members an opportunity of welcoming Dr. and Mrs. Pearson on their return from England and the United States of America.

In addition to the lectures given at the ordinary meetings scientific papers were submitted for publication and have been printed in the present volume.

Library

During the year 600 volumes were added to the Library in addition to a number of reports and pamphlets from British and Foreign Institutions and learned Societies. The number of Institutions on the Exchange List for the year was 270, and new exchanges were arranged with the following Institutions:—Bulgarian Academy of Sciences, Director of Botanical Museums, Ceylon; Musei Nationalis, Prague; Cesdoslovemska Botanicka Spolecnost, Prague; Entomologische Forentngm Universitats Zoologische Museum, Copenhagen; Indian Academy of Sciences, Bangalore; Rancho Santa Anna Botanic Gardens, California.

The Library now consists of 24,132 volumes.

Cataloguing the Library

The Council desires to acknowledge the help given by the University authorities in permitting Miss Megan Griffiths, B.A., Cataloguer at the University of Tasmania's Library, to direct the cataloguing of the Society's Library. During the year under review Miss Griffiths has put in full time in the Society's Library doing this work.

Membership

The Society consists of the following members:—

Honorary members		2
Corresponding members		3
Ordinary members—		
Class A	221	
Class B	136	
		357
Life members		25
Associate members		25
		412

During the year 17 names were removed from the List of Members owing to deaths, resignations, &c., and 33 new Ordinary Members were elected. (Also one Ordinary Member became a Life Member and five Associate Members became Ordinary Members.)

Deaths

The Council regrets having to record the deaths of the following members during the year:—Mr. H. R. Hutchison (1909), Mr. C. E. Radcliff (1935), Mr. B. J. Cronly (1936), Mrs. H. Shaw (1944), Mr. H. L. Dakin (1944), Dr. R. W. Lawrence (1946).

Purchase of Slides Belonging to the late Dr. A. N. Lewis

During the year under review the Executors of the estate of the late Dr. A. N. Lewis offered the Society his collection of geological lantern slides, together with the cabinet. The Government made a special grant of £100 to the Society in order to buy this collection on condition that the Society would make the collection available to the Education Department and the University of Tasmania.

Public Address System (Loud Speakers)

On the occasion of a special meeting when a large number of people are present in the Society's room it has been found that people at the back of the Hall have had difficulty in hearing some the speakers. This difficulty has now been got over by the purchase of a loud speaker apparatus (public address system) and this has been used with success on the occasion of some of our larger meetings. The cost of purchasing this apparatus (£43 17s. 6d.) was made from the Life Membership Fund.

Purchase of Film Strip Projector

The same fund was also used for the purchase of a film strip projector (£32 1s. 1d.).

Captain D. C. Pearse

During the year Capt. D. C. Pearse, who had filled the post of Assistant Secretary for some years, asked to be relieved of his duties and Mr. D. Martin has been appointed in his place. Capt. Pearse was thanked for his valuable services at the Council Meeting held on 28th June, 1949, and by members of the Society at the General Meeting held on 5th July, 1949.

Appointment of Hon. Solicitor

During the year under review Mr. F. C. Wolfhagen was appointed Hon. Solicitor to the Society.

Papers and Proceedings

As in previous years the Government has borne the cost of printing the Papers and Proceedings and have agreed in future to provide a sum not exceeding £400 for this purpose.

Gifts to the Society

The following is a list of gifts to the Society during the year, in addition to the numerous exchanges received from British and Foreign Institutions:—

Mr. K. R. von Stieglitz: Midland Pioneers; A short History of Ross with some tales of the Pioneers.

The Royal Empire Society Scientific Congress Report, vols. 1-2, presented by the Executive Committee C.S.I.R.O.

The Australian Environment: Presented by the Conference Committee, Specialist Conference in Agriculture, Aus. 1949.

A Botanist in Southern Africa: Portion of cost provided by Mrs. C. F. Charles.

Papers of the Dorcas Society.

Journal of Peter Harrisson, 1822.—From Mrs. J. Bruford, on condition that a typescript copy of the Journal be made and given to Mrs. Bruford.

Further gifts bearing on the Franklins, from the Scott Polar Research Institute, Cambridge—

(a) 4 water colour sketches.
(b) 3 satin Regatta programmes.
(c) A pencil sketch of Sir John Franklin on Swan Is.
(d) 4 letters about and to the Franklins, 1843-73.
(e) The resolution and letter sent to Lady Franklin in 1868 by the Legislative Council of Tasmania thanking her for her gift of Betsy Island.

The Royal Society of Tasmania.

Statement of Receipts and Payments for Year ended 31st December, 1949.

Receipts.

	£	s.	d.	£	s.	d.
Balance from last account				15	12	2
Subscriptions—						
A 222	333	0	0			
B 129	135	9	0			
Assoc. 23	11	10	0			
Exchanges	0	2	6			
				480	1	6
Sale of publications				44	11	11
Rentals, &c.				48	11	9
Sale of Mackaness Brochure				12	12	0
Transferred from Life Membership Fund for equipment				88	8	7
Transferred from Funds for Books, 1949				39	9	11
Govt. Grant for purchase of lantern slides, late Dr. A. N. Lewis				100	0	0
				£829	7	10

Payments.

	£	s.	d.
Salaries	191	11	1
Light and power	60	11	1
Library	60	4	1
Stationery, printing and advertising	15	11	4
Northern Branch, share of subscriptions	35	10	6
Postage of Papers and Proceedings	16	8	1
Miscellaneous	11	2	9
Purchase of public address system	43	17	6
Purchase film strip projector	32	1	1
Purchase map cupboard	10	0	0
Purchase binding cloth	11	16	10
Insurance	9	12	7
Trustees late A.N. Lewis, for slides	100	0	0
Expenses conversazione, 15th March	19	14	6
Transferred to Reserve Account	100	0	0
Petty cash (cash on hand 31.12.49, £1 6s. 7d.)	51	0	0
	769	1	5
Balance to next account	60	6	5
	£829	7	10

S. Angel, Hon. Treasurer.
A. Hewer, Hon. Auditor.

W. L. Crowther, Vice-President.
Joseph Pearson, Hon. Secretary

Royal Society Funds.

Statement of Balances for Year ended 31st December, 1949.

	£	s.	d.
Reserve Account	100	14	8
Life Membership Fees	230	18	1
Clive Lord Memorial Fund (£200)	12	3	11
R. M. Johnston Memorial (£232)	2	3	10
Morton Allport Memorial Fund (£200)	6	0	6
A. H. Clarke Bequest (£100)	0	19	3
Milligan Bequest (£150)	9	10	1
A. N. Lewis Memorial Fund	22	12	4

Abstracts of Proceedings

15TH MARCH, 1949

Annual Meeting

The Annual Meeting was held in the Society's Room, Tasmanian Museum. His Excellency the Governor, President of the Society, presided.

The following Office-bearers were elected for 1949:—Mr. A. L. Meston was elected Vice-President for two years in the place of Mr. W. H. Hudspeth, who retired under Rule 12; Honorary Secretary, Dr. J. Pearson; Assistant Honorary Secretary, Mr. D. Martin; Honorary Treasurer, Mr. S. Angel; Honorary Auditor, Mr. H. J. Exley.

The following were elected members of the Council for 1949: Mr. W. H. Hudspeth and Mr. F. C. Wolfhagen were elected for three years in the place of Professor V. V. Hickman and Mr. J. Somerville, who retired under Rule 21. Mr. D. Martin was elected for a term of two years in the place of Mr. A. L. Meston who had been elected Vice-President.

The following were elected members of the Society:—Miss T. F. Masters, Mr. W. J. Sutherland, Ross, Mr. Walter Sutherland.

Dr. Joseph Pearson, Director of the Tasmanian Museum and Art Gallery, delivered a lecture entitled 'The Modern Museum', of which the following is an abstract:—

Dr. Pearson gave an account of his visit to Britain and U.S.A. in 1948-49.

Museums in Britain had suffered greatly from effects of the war, not so much by war damage as by the suspension of all building and developmental schemes, and the effects of the war will be felt for many years to come. He was able to arrange a further loan of pictures with the Trustees of the Tate Gallery. Seven pictures have been lent but they are not of such a high artistic standard as those included in the previous loan.

Dr. and Mrs. Pearson visited the U.S.A. as the guests of the Carnegie Corporation of New York. The visit lasted about ten weeks and it was found necessary to concentrate on the Museums of the Eastern States. The principal cities visited were New York, Washington, Boston, Chicago, Cleveland, Brooklyn, Providence, and the Universities of Harvard and Yale.

The following may be regarded as the salient features of modern museum development in America:—

1. Utilization of artificial light. This solves many architectural problems but also provides new ones. It is found that the use of artificial lighting is more effective and makes good display easier.
2. The popularity of large and expensive habitat groups.
3. The importance of linking the museums with school education.
4. The emphasis placed upon research by museum staffs and the generous provision of research laboratories and storage space for reserve collections.
5. Great civic interest taken in museums shown partly by the large private benefactions and by the provision of beautiful buildings.
6. The amenities of the public are considered. Hence comfortable heating arrangements and the provision of cafeterias.

Dr. Pearson thought that the many lessons which the modern museums of Britain and U.S.A. could teach would be lost if one's sense of proportion was not maintained. The special problems of museum development in Hobart might have their best solution if a close liaison were set up between the University and the Museum. The history of the

Tasmanian Museum showed clearly that the present system of administration by a Board of Trustees had not been very successful. The lecturer felt that the question of establishing a closer link with the University, even to the extent of building a new museum on the University site, should be given serious consideration.

Dr. Pearson also spoke of his activities while abroad in carrying out embryological investigations in the Embryological Department of University College, London. He also gave lectures on his marsupial researches at the Linnean Society of London, the University of Edinburgh, the Universities of Yale and Harvard, and the American Museum of Natural History, New York.

5TH APRIL, 1949

A meeting was held in the Society's Room. Mr. A. L. Meston, Vice-President, presided.

The following were elected members of the Society:—Mrs. F. M. Brownhill, Miss G. Madder, Dr. G. Sibthorpe, Mr. G. W. Colman, Mr. D. L. Hollis, Mr. D. M. Paton, Mr. C. G. Ryan, Mr. E. G. Terry.

Mr. D. Martin delivered an illustrated lecture entitled 'Eucalyptus Trees in the British Isles', of which the following is an abstract:—

The first record of cultivation of Eucalyptus in the British Isles was that of Aiton in 1789 who listed *E. obliqua* as growing at Kew. This seed was collected at Adventure Bay by Tobias Furneaux of the 'Adventure' of Cook's second voyage.

The cultivation of Eucalyptus in Europe boomed after 1850 as the result of von Mueller's enthusiasm and the belief that the oil was a specific for malaria. *E. globulus* in particular was widely planted but this was an unfortunate choice as this species is sensitive to frost and the timber, though fast growing, is difficult to season. Very few trees of this species now survive.

Following von Mueller's taxonomic work, collections of Eucalyptus were laid down in the 70's and 80's by wealthy amateurs but though they flourished for a time, most have declined owing to severe winters killing all but the hardiest species. The healthiest of the collections of this period are at Loch Hourn in Invernesshire where there are several hundred trees, embracing *E. coccifera, E. johnstoni,* and *E. urnigera,* and Rostrevor, co. Down with *E. coccifera, E. cordata, E. suborenulata, E. urnigera, E. ovata,* and *E. biangularis.*

About the turn of the century, further collections were laid down of which, Mt. Usher, co. Wicklow is now the most comprehensive and best maintained. It includes *E. amygdalina, E. stuartiana, E. delegatensis, E. gigantea, E. macarthuri, E. johnstoni, E. pulverulenta, E. urginera, E. viminalis, E. virgata,* and *E. coccifera.*

Interesting introductions of single species were that of *E. gunnii* by Charles Balfour at Whittingehame, *E. lothian* in 1846, and J. Bateman at Brightlingsea, Essex, in 1887. A tree of the former is still healthy and is probably the oldest Eucalyptus outside its natural habitat. The seed for the latter did not come direct from Australia but from Argentina.

The survival of the different species in England gives useful information on their frost resistance. The hardiest are *E. nipophila, E. gunnii. E. vernicosa, E. parvifolia, E. coccifera, E. urnigera, E. subcrenulata* which have survived temperatures below 5° F.

3RD MAY, 1949

A meeting was held in the Society's Room. Mr. A. L. Meston, Vice-President, presided.

The following were elected members of the Society:—Miss D. Alcock, Miss B. Scott, Mr. R. Shoobridge, Mr. H. M. Wilson.

Mr. L. W. Miller delivered an illustrated lecture entitled 'A Survey of the Aphids in Tasmania', of which the following is an abstract:—

Aphids, also known as blight or green flies are sap sucking plant bugs which are of considerable importance, not only for the damage they do, but also because they spread some of the most serious plant virus diseases. They are essentially insects of the Northern Hemisphere there being only about four native species in Australasia none of which have been recorded in Tasmania.

Most of the commercial crops, ornamental trees, and flowers, grown in Tasmania are of European or North American origin. Unfortunately at the time of the introduction of such plant species here no precautions were taken against the insects that they were carrying. Thus we find that a number of old world aphid species have been allowed to become established in Tasmania.

A detailed survey has revealed that there are approximately 50 species of aphids in Tasmania infesting many different types of imported plants the bulk of which are of importance to the State.

There are still a great many aphid species in either England or North America that have not yet reached Tasmania. Some of these are major pests of such important crops as apples, pears, raspberries, and peas. Every effort should therefore be made by the Commonwealth Plant quarantine authorities to prevent the accidental importation of any of these aphid pests into Tasmania.

7TH JUNE, 1949

A meeting was held in the Society's Room. His Excellency the Governor, President of the Society, presided.

The following were elected members of the Society:—Miss R. de Little, Mr. R. P. Mather.

Mr. N. R. Laird delivered an illustrated lecture entitled 'The Australian Antarctic Expedition' (see p. 285).

5TH JULY, 1949

A meeting was held in the Society's Room. Dr. W. L. Crowther, Vice-President, presided.

Mr. F. R. S. Hutchison was elected a member of the Society.

Members were given an opportunity to peruse further documents, &c., relating to Sir John and Lady Franklin, which had been presented by the Scott Polar Research Institute, Cambridge.

Mr. E. R. Guiler delivered an illustrated lecture entitled 'Marine Littoral Ecology', of which the following is an abstract:—

The physical and biological environments were discussed in a general sense. In Tasmania the tides play a very great part in the control of life on the shore. The tidal range is small the average rise and fall over a period of twelve months being only 1′ 10½″. The tides show diurnal inequality. During the period April to October the morning tide is larger than the afternoon but at the equinox the afternoon tide becomes the larger. Due to this inequality of the tides there occurs a very sharp increase in the amount of time the shore above the average level of the low high and high low tides is exposed to the air. This is a 'lethal' level. Above this on the shore there are very few species to be found while below it there is a rapidly increasing shore life. There are also critical levels on the shore above and below the lethal level. The critical levels are difficult to distinguish when they occur above the lethal level.

A typical zonation on a rocky shore in Southern Tasmania might read—

Lichens	
Bare Rock	
Melaraphe unifasciata	H.H.W.
Bembicium nanum	
Elminius plicatus and *E. modestus*	Lethal Level.
Patelloida alticostata	
Galeolaria sp.	M.T.L.
Brachyodontes erosus and *Catophragmus polymerus*	
Mytilus planulatus	L.L.W.

Below the lethal level only index species are given but above it the species on the above zonation are all that can be found in many places. A salient feature is the absence of algae. Algae are only found below *Galeolaria* or very poorly developed in pools.

Air and sea temperatures were discussed. The effect of extreme cold on the littoral fauna was illustrated from the results of the very cold winter of 1946-7 in Northern Ireland. Where the ice sheet covered the foreshore and was unbroken there was very little effect on littoral life. When the ice sheet was broken and the cold winds were allowed to penetrate to the forms dwelling below the ice very great slaughter ensued. The ice sheet ended about the zone of *Fucus serratus* and the Laminaria zone and the fauna thereof suffered very considerably. *Ostrea edulis*, *Paphia* sps., *Chlamys opercularis*, and annelids were found dead in thousands.

2ND AUGUST, 1949

A meeting was held in the Society's Room. Mr. A. L. Meston, Vice-President, presided.

The Chairman reported that Capt. D. C. Pearse had resigned from the position of Assistant Hon. Secretary and that, under Rule 10, this casual vacancy could be filled at a general meeting. Mr. D. Martin, M.Sc., was unanimously elected to this office.

The following were elected members of the Society:—Miss H. M. W. Shoobridge, Mr. P. S. Young, Mr. P. Anderson, Dr. G. M. W. Clemons, Mr. E. L. Garrott, Mr. F. J. Gunn, Mr. W. E. Tucker, Mr. C. L. Willes.

Dr. C. A. Duncan exhibited a photo micrograph of a new Trypanosome which was found in the blood of a platypus. This discovery was made accidentally in the course of preparing blood samples of the platypus in the Museum laboratory and the samples were taken to Dr. Duncan's laboratory for staining and the Trypanosomes were found in the stained preparations. Subsequently Dr. Duncan ascertained from authorities in Sydney that this Trypanosome is a new species and he proposes to call it *Trypanosoma binneyi.*

Mr. G. C. Wade delivered an illustrated lecture entitled 'Some Diseases of Ornamental Plants', of which the following is an abstract:—

Diseases in plants may result from a number of different causes. Some are caused by the invasion of the plant by another organism, which is parasitic on the host plant. However, disease may result from something wrong with the environment of the plant. Of these non-parasitic diseases those due to deficiencies of various essential elements, or to excesses of various substances in the soil are particularly important.

The most important parasitic diseases are those due to eelworms, bacteria, fungi, and viruses. Example of diseases of ornamental plants due to members of each of these groups was discussed. Those chosen illustrated different types of symptoms which may be produced by the attack of a parasite.

Eelworm disease of bulbs such as hyacinths, tulips, and narcissus causes a brown rot of some of the bulb scales, while others remain sound. Such bulbs may be entirely killed or produce stunted plants. The disease is controlled by holding the bulbs in hot water at such a temperature that the eelworms are killed without affecting the bulb.

In some diseases, the parts of the plant which are attacked grow excessively so that galls are produced. Crown gall is due to infection by bacteria, which stimulate the affected part to grow excessively so that large galls are produced. This infection usually occurs in the nursery, and it does not often spread to established plants. The fungus Exobasidium attacks the leaves of azaleas and rhododendrons causing them to become greatly enlarged. This trouble is easily controlled by spraying with a copper fungicide.

Several common leaf infecting fungus diseases were discussed, and the control measure described.

Collar and root rot diseases are due to fungal attack at the base of the plant, and such diseases result in the death or stunting of the plant. When young seedlings are affected in this way, the trouble is referred to as 'damping-off'. Crop rotation or soil sterilisation are the best methods of combating these diseases. In some cases resistant varieties of plants can be used, and treatment of the seed is effective in some cases.

Gladioli are subject to a number of important diseases. Botrytis corm rot gains entry to the corms after they have been dug and spread internally producing a soft rot. As the fungus is inside the corm it is useless to treat affected corms, but the trouble can be prevented by dipping the corms in a mercury fungicide as soon after digging as possible. In this way the fungus is unable to gain entry to the corms. Hard and dry rot are also due to fungi, and produce hard irregular scabs on the surface of the corms. The same fungi cause diseases of the growing plant. They are rather difficult to combat, but crop rotation and selection of disease free corms are very important measures. Dipping the corms in corrosive sublimate is of some value, but it is not completely effective as the scabs are so hard that the fungicide cannot penetrate very well. Bacterial scab may be recognised by circular concave scabs with a definite raised margin. This trouble can be controlled by dipping in corrosive sublimate, and by growing the plants in well-drained soil.

Virus diseases infect many ornamental plants. They are due to very small infective agents, many being carried by sucking insects, and bulbs from infected plants always carry the disease. The symptoms often consist of mottling of the foliage with pale coloured areas, and breaking of the flower colour. They are controlled by removing infected plants so that the disease does not spread, and by only saving bulbs from healthy plants.

6TH SEPTEMBER, 1949

A meeting was held in the Society's Room. Dr. W. L. Crowther presided.

The following were elected members of the Society:—Mr. L. E. Luckman, Dr. A. G. Nicholls.

Mr. M. R. Banks delivered an illustrated lecture entitled 'Radioactivity and the Age of the Earth', of which the following is an abstract:—

Early estimates of the age of the earth are given which in general tend to be too small. Examples are 1,972,949,050 years by a Hindu philosopher, 5953 by Bishop Ussher, and several estimates ranging from 20,000,000 to 100,000,000 years by nineteeth century geologists and physicists.

Several astronomical estimates are mentioned and these indicate ages between 1,000,000,000 years and 10,000,000,000 years with the probable age closer to one thousand than to ten thousand million years and probably less than four thousand million years.

Radio-active estimations are now well established. These depend on the spontaneous disintegration of elements such as uranium, thorium, and rubidium to form lead and strontium respectively. The decomposition proceeds at a constant rate and by analysing radioactive minerals the uranium and the lead content are determined, the age is then found by dividing the lead by the uranium content and multiplying by the disintegration rate. The oldest mineral thus treated is 1985 million years old and this is considerably younger than the rocks in which it was found.

Rubidium also disintegrates to form strontium and by applying a similar procedure to that adopted for uranium, a mineral 2100 million years old has been found. This again was formed well after the earth had cooled down.

Recently Professor Arthur Holmes evolved a method for comparing the composition of lead ores and as a result of this is able to fix the minimum age of the earth at 3350 million years and the maximum at 5400 million years. In this he used lead ore from Broken Hill with an age of 1200 million years among others.

New and untried methods involving the radioactivity of rubidium and potassium may may eventually make it possible to find the age of sediments such as limestone and shale and even determine the absolute age of fossils to within a million years. This may well alter our ideas on rock structure and add greatly to our knowledge of evolutionary processes.

4TH OCTOBER, 1949

A meeting was held in the Society's Room. Dr. W. L. Crowther presided.

The following were elected members of the Society:—Mr. T. H. O. Phillips, Mr. H. G. Cross.

The following illustrated lectures were given:—

(1) 'A Slab of Ancient History', by W. H. Hudspeth. (See page 77.)

(2) 'Camping Grounds of the Tasmanian Aboriginals', by Dr. W. L. Crowther. (See page 83.)

1ST NOVEMBER, 1949

A meeting was held in the Society's Room. Professor S. W. Carey presided.

The following were elected members of the Society:—Rev. A. A. Gray, Mr. W. D. Jackson, Dr. G. M. Parker.

The following papers which had been submitted for publication in the Society's Journal were tabled, and it was agreed to submit them to the Standing Committee:—

(1) Geology of the Queenstown District, Tasmania. By John Bradley.

(2) The Gordon River Limestone of Tasmania. By S. Warren Carey and M. R. Banks.

(3) Structure and Stratigraphy of Hobart District. By S. Warren Carey.
(4) Geology of the Junee-Adamsfield Area, Tasmania. By S. Warren Carey.
(5) A Revision of Tasmanian Psocoptera with Descriptions of New Species. By B. A. B. Edwards.
(6) Distribution and occurrence of Sponges in Tasmania. By E. R. Guiler.
(7) *Fabia hickmani* (Pinnotheridae) sp. nov. from the Mussel *Mytilus planulatus*. By E. R. Guiler.
(8) A Revision of the Tasmanian Hydroida. By M. M. Hodgson.
(9) Notes on the Life History of *Gonothyraea hyalina* Hincks. By M. M. Hodgson.
(10) Further note on the female urogenital system of Hypsiprymnodon. By Joseph Pearson.
(11) The female urogenital system of the Dasyuridae. By Joseph Pearson.
(12) The female urogenital system of Thylacinus. By Joseph Pearson.

Professor V. V. Hickman delivered an illustrated lecture entitled 'The Morphology and Habits of Spiders', of which the following is an abstract:—

> The general anatomy and segmentation of the spider's body were described. Reference was made to the distinguishing features and geographic distribution of the Liphistiomorphae, Mygalomorphae, Hypochilomorphae, and Araneomorphae. The structure and arrangement of the eyes of the Argiopidae, Lycosidae, and Salticidae were considered in relation to the visual powers of these spiders. Illustrations of the different forms of spinning apparatus were shown and the employment of the silk in making webs, egg-sacs, &c., described. The various types of nests made by the Mygalomorphae were mentioned. Examples of mimicry and protective resemblance were shown on the screen and discussed. The habits of spiders belonging to the genera *Atrax* and *Latrodectus* were described and the poisonous effects of the bite of these spiders mentioned.

The Hon. Secretary reported that an invitation had been received from the Connecticut Academy of Arts and Sciences to appoint a delegate to attend the one hundred and fiftieth Anniversary Meeting, which also would be the one thousandth Meeting of the Society, to be held on the 4th November, and that in consequence a telegram had been sent to Professor Theodore Sizer, of Yale, asking him to represent the Royal Society of Tasmania on that occasion and to convey to the Academy the Society's greetings. The action of the Hon. Secretary was approved by the meeting.

Northern Branch

Annual Report for 1949

The Council submitted the following record of activities in 1949:—

In presenting this Annual Report of the Branch's activities during 1949, your Council wishes to draw particular attention to a matter of interest to all members of the Branch. Our membership now comprises nine Life Members and seventy-three Ordinary Members, an increase of sixteen over last year. This is an indication of the part that the Branch is beginning to play in our cultural life. Your Council now feels that the Branch is in the position to carry on an active existence of its own while still linked closely with the parent Society in its general aims. The Society will therefore be asked to grant the Branch a considerable measure of control of its own affairs.

Action taken by the Branch led to the formation of the Launceston Field Naturalists' Club in October 1949 and this Club is now doing active work. There is a definite need for a Club of this sort in Launceston and its future progress should be marked.

The Tasmanian Historical Society went into recess recently and has transferred its assets and property to the Branch. The Branch has agreed to incorporate the Society and to use the funds transferred for historical research.

Six meetings were held during the year, of which the two meetings in May were held in conjunction with the Northern Tasmanian Fisheries Association:—

April 28th 1949	Prof. S. W. Carey: 'The Ascent of Life'.
May 16th 1949	Prof. E. Percival: 'Freshwater Fisheries Problems'.
May 25th 1949	Mr. D. Butcher: 'Freshwater Fisheries Problems'.
July 6th 1949	Mr. N. R. Laird: 'Macquarie Island'.
August 4th 1949	Dr. Loftus Hills: 'Science and Civilisation'.
November 18th 1949	Mr. Crosbie Morrison: 'Our Natural Inheritance'.

MEETINGS

April 28, 1949

Annual General Meeting

The Annual General Meeting was held at the Museum, Mr. J. E. Heritage presiding.

The Annual Report and Balance Sheet for 1948 were adopted.

The Office-bearers for 1949 were elected.

A lecture was then given by Professor S. W. Carey, entitled 'The Ascent of Life'.

In his lecture, which was illustrated with lantern slides, Professor Carey dealt with the progress of evolution of life on the earth from the evidence of the geological record. He traced the gradually increasing complexity of life as one geologic period succeeded another, finally culminating in the Primates. Professor Carey showed something of the great changes that have occurred in the faunas from age to age, and how various groups have dominated, later to decline in importance, with many of them now no longer existing.

May 16, 1949

A meeting was held at the Museum, Mr. J. E. Heritage presiding.

Professor E. Percival, Professor of Biology at Canterbury University College, Christchurch, New Zealand, spoke on Freshwater Fisheries Problems.

In introducing the speaker, Mr. Heritage stressed the need for biological survey in Tasmania, such studies being particularly urgent in view of disappearing life forms and changing environments. He asked members and others to co-operate with the Society in this work.

In his address, Professor Percival first reviewed freshwater fisheries work overseas and in New Zealand, emphasising the need for research to provide the basic data for the study of fisheries problems.

Professor Percival then went on to deal with Tasmanian problems and here he found that the absence of information made it difficult to assess the state of the fishery. Much could be done, however, if those interested undertook certain investigations, he said.

Among matters referred to were the collecting of catch records, the maintenance of stocks of fish by hatchery stocking and natural reproduction, the fertilising of waters to increase food supplies and the introduction of food organisms from other areas.

In conclusion, Professor Percival made a special plea for the preservation of remaining virgin waters in Tasmania in their original state. He pointed out that others besides anglers were interested in fresh waters and that some should remain free from introduced organisms.

MAY 25, 1949

A meeting was held at the Museum, Mr. J. E. Heritage presiding.

Mr. Dunbavin Butcher, Director of the Fisheries and Game Department of Victoria, spoke on Freshwater Fishing Problems.

Mr. Butcher described the work of his Department in studying and developing freshwater fisheries in Victoria. He said that the basis of this work was a thorough study of the biology of fresh waters and that activities would be concerned with meeting the need for increased intensity of fishing. This can be done only by management of existing waters.

Mr. Butcher stressed the importance of the chemical constitution of the water, in particular pH and amounts of phosphate and nitrate.

JULY 6, 1949

A meeting was held at the Public Library Hall, Mr. J. E. Heritage presiding.

Mr. Norman R. Laird, Official Photographer and Tasmanian Government representative on the Australian Antarctic Expedition, 1948, spoke on Macquarie Island and the work of this expedition there. Mr. Laird first dealt with the history of the island from its discovery by Frederick Hasselburg of the sealer 'Perserverance' in 1810; the orgies of sealing, first a few years of hunting the fur-seal, which by 1815 had been practically exterminated, and then the elephant-seal for its blubber, its extermination being nearly complete by 1829; later sporadic visits for sealing, culminating in the establishment by Joseph Hatch of his infamous industry to obtain penguin and seal oil; and the visits of such notable exploring and scientific expeditions as those led by Bellinghausen (1820), Wilkes (1840), Scott (1901), Shackleton (1909), and Mawson (1911).

Mr. Laird then showed photographs taken during his visit to Macquarie Island, these including a very fine series dealing with topography and natural history.

In closing the meeting, the Chairman referred to the need for biological survey in Tasmania and said that the Branch was taking the matter up actively.

AUGUST 4, 1949

A meeting was held at the Museum, Mr. J. E. Heritage presiding.

Dr. Loftus Hills spoke on 'Science and Civilisation'. In introducing Dr. Hills, the Chairman recalled that he had given the inaugural lecture at the Branch in 1921.

'Science and Civilisation' is a complex statement, with science and civilisation intimately associated. Civilisation grew up and decayed before modern science existed with its exact observation, exact measurement, exact thinking and precise language. Modern science began with Galileo who set science on the path of steady progress, and for the last 400 years science has been able to contribute more and more to facilitate the process of civilisation.

The pure science of to-day is the technology of to-morrow. Nowhere is this more true than in the use of atomic energy. The use of nuclear fission processes has the greatest possibility for good in civilisation, although up to the present almost its only use has been the destruction of human life, which is another example of the way in which science has developed far ahead of political organisation.

Science has developed a terminology and nomenclature free from nationality whereas in everyday use the meaning of words has become corrupted. Capitalism, democracy, socialism, nationalism, communism, there are hundreds of definitions of each of them rather than scientific definition. Plato long ago pointed out that one of the symbols of evolution is that words lose their meaning.

Dr. Loftus Hills concluded by saying, 'free interchange of ideas is necessary for progress'.

NOVEMBER 18, 1949

A meeting was held at the Museum, Dr. C. Craig presiding.

Mr. Crosbie Morrison, President of the Royal Society of Victoria, gave a lecture entitled 'Our Natural Inheritance', illustrating it with colour films.

He discussed first the radiation of reptiles and mammals from their centre of evolution, which he placed in Asia Minor, pointing out that the less successful forms were elbowed out as new types evolved and finally reached the periphery. The Marsupials thus came to Australasia and the Americas and in Australia were the dominant land mammals because of the changes in land connection associated with Wallace's Line.

Mr. Morrison went on to show how Australia's unique mammal fauna was but one point of interest, most groups of animals and plants in Australia providing special opportunities for study. The need to conserve this unique fauna and flora was urgent. He instanced the Cape Barren Goose and commented on the conditions which could permit the present destruction of these birds.

Mr. Morrison illustrated his talk with five colour films comprising (1) plant life, (2) the giant earthworm, (3) and (4) birds, and (5) mammals.

Office-bearers, 1949

Chairman: J. E. Heritage, C.M.G., LL.B., 1949.

Vice-Chairman: Gilbert McKinlay, 1949.

Council: Hon. R. K. Green, M.L.C., LL.B., 1949; W. K. McIntyre, M.C., B.E., M.D., F.R.C.O.G., 1949, 1950; C. G. Ryan, 1949, 1950; K. R. von Stieglitz, 1949.

Hon. Secretary-Treasurer: N. J. B. Plomley, M.Sc. (1949).

Royal Society of Tasmania.

Northern Branch.

Statement of Accounts at February 28, 1950.

Receipts.	£	s.	d.	Expenditure.	£	s.	d.
Balance at March 1, 1949	38	11	6	Lectures	11	8	10
Subscriptions	48	0	6	Library	11	5	3
Tasmanian Historical Society	5	15	9	Postage and stationery	6	0	0
Bank interest	0	11	4	Petty cash	4	4	1
				Miscellaneous	6	0	0
				Balance forward	54	0	11
	£92	19	1		£92	19	1

Obituary

Robert Hall (1867-1949)

Robert Hall, whose death occurred at Hobart on September 19, 1949, was a former Curator of the Tasmanian Museum and also an ornithologist of distinction. In latter years, however, with indifferent health, he had little association with scientific activities, although he remained a 'bird lover' to the end, and his knowledge continued to be imparted freely to students.

He died at the age of 81, leaving as his memorial several books on Australian ornithology; whilst there were few ornithological publications in Australia and abroad in which articles from his pen were not featured during his earlier years. Past numbers of *The Emu*, *The Victorian Naturalist*, and *The Tasmanian Naturalist* contain several of his papers, many of value to-day. The books he wrote included *A Key to the Birds of Australia and Tasmania* (1899), *Insectivorous Birds of Victoria* (1900), *Some Useful Birds of Southern Australia* (1907), and *Australian Bird Maps* (1922).

A foundation member of the Royal Australasian Ornithologists Union, he was also its president for a time. Before coming to Hobart in 1908 to accept the position of Curator of the Tasmanian Museum, he lived in Melbourne, and it was from there that he left in 1903 for a trip to Siberia, being probably the first British naturalist to travel to the mouth of the Lena River. On that expedition he collected bird specimens to the number of 401 and added considerably not only to the knowledge of Siberian ornithology, but also of the movements and breeding areas of migrant birds from Tasmania and Australia; the skins went to Rothschild's museum at Tring.

Mr. Hall also collected birds in Northern India and on Kerguelen Island. Honours which were awarded him included that of Corresponding Member of the Zoological Society of London and a Fellowship of the Linnean Society.

Himself a taxidermist of considerable ability, Mr. Hall did much to build up the bird skin collection of the Tasmanian Museum which contains many of his beautifully executed specimens.

M.S.R.S.

H. H. Pimblett, Government Printer, Tasmania.

PAPERS AND PROCEEDINGS

OF

THE ROYAL SOCIETY OF TASMANIA

FOR THE YEAR

1950

Edited by

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Papers and Proceedings, 1950

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Pap. & Proc. Roy. Soc. Tasmania, 1950 (15th December, 1951)

The Identity of Spiders belonging to the Genus *Amaurobioides* Cambridge

By

V. V. Hickman

Ralston Professor of Biology, University of Tasmania

(Read 14th November, 1950)

Summary

The validity of the three species, *Amaurobioides litoralis* Hickman, *Amaurobioides africanus* Hewitt and *Amaurobioides piscator* Hogg is discussed. All three are regarded as synonymous with *Amaurobioides maritima* Cambridge.

Four species of spiders belonging to the littoral genus *Amaurobioides* Cambridge have been described, namely—

Amaurobioides maritima Cambridge, 1883, from Allday Bay, Otago, New Zealand.

Amaurobioides piscator Hogg, 1909, from Campbell Island, south of New Zealand.

Amaurobioides africanus Hewitt, 1917, from East London, South Africa.

Amaurobioides litoralis Hickman, 1949, from Eaglehawk Neck, Tasmania.

In my description of *A. litoralis* I stated that there was a close resemblance between it and *A. maritima* Cambridge. However, according to Cambridge the cephalothorax of *A. maritima* was twice as long as it was broad. Moreover, his figure of the maxillae and labium showed the labium without lateral excavations at the base (See Cambridge, 1883, Plate XXXVI, fig 3e). In *A. litoralis* the cephalothorax measured only one and a half times as long as it was broad and the labium had lateral excavations at the base. On the assumption that Cambridge's description of the cephalothorax and figure of the labium of *A. maritima* were correct, the Tasmanian spider, *A. litoralis*, was considered to be a different species and described as such.

Through the courtesy of Professor B. J. Marples I have now received adult male and female specimens of *A. maritima* from Dunedin. These were collected from a locality near that from which the type specimen came. An examination of these spiders shows that Cambridge's statement of the size of the cephalothorax and his figure of the labium are incorrect. The cephalothorax of an adult female measures 6·09 mm. long and 3·89 mm. wide, and the labium is excavated on each side near the base.

A comparison of the Dunedin specimens with examples of *A. litoralis* from Tasmania shows no significant difference between them in either sex. The two spiders undoubtedly belong to the same species.

In regard to *A. africanus* Hewitt there also appears to be some doubt as to the validity of the species. Hewitt (1917, p. 705) states that he submitted immature examples from East London to Mr. H. R. Hogg, who compared them with the types of *A. piscator* from Campbell Island and 'was unable to find any essential difference' between the spiders from the two localities. Hewitt, however, regarded the epigynal character of the adult female of *A. piscator*, as figured by Hogg,

quite distinct from that of *A. africanus*. Hogg, on the other hand, considered the difference between the two epigyna as remarkably small (See Hewitt, 1917, p. 710).

On comparing the characters described by Hewitt for *A. africanus* with those of *A. litoralis* from Tasmania and *A. maritima* from Dunedin, a close resemblance between the three spiders is at once apparent. Colouration, abdominal pattern, relative lengths of the appendages and the arrangement of spines on the legs are much the same. Projecting from the apex of the tibial segment of the palp in an adult male from Dunedin is a long straight stiff process gradually tapering to a fine point, just as there is in *A. africanus* and *A. litoralis*. The short finger-like process, which Hewit describes as being on the opposite side of the tibia in *A. africanus*, is also present in the New Zealand spider. In my description of *A. litoralis* the process was overlooked but a re-examination of a male from Eagle-hawk Neck shows it to be present. In my opinion the South African, Tasmanian and New Zealand spiders all belong to the one species, *A. maritima* Cambridge.

In regard to *A. piscator* Hogg there seems to be very little difference between it and *A. maritima* Cambridge. Hogg (1909, p. 165) states that in general form, size, pattern on back of abdomen, and arrangement of the eyes, *A. piscator* very closely resembles *A. maritima*. However, he distinguishes the former from the latter species by its having a shorter cephalothorax, spines on the femora and the first, second and fourth pairs of legs equal in length.

As shown above, measurements of specimens of *A. maritima* from Dunedin indicate that Cambridge is incorrect in stating that the cephalothorax is twice as long as it is broad. According to Hogg's measurements there is not a very great difference in the size of the cephalothorax in *A. piscator* and that of the cephalothorax in the Dunedin specimens of *A. maritima*.

The relative proportions of the legs in *A. litoralis*, *A. africanus* and *A. piscator* are practically the same. The first, second and fourth pairs of legs in each case are sub-equal in length and the third pair the shortest. Cambridge does not record the exact measurements of the legs of the type specimen of *A. maritima* but merely gives the leg formula as 1. 4. 2. 3, stating that the difference between 1 and 4 is very slight. In the specimens from Dunedin the relative proportions of the legs agree with those of the other three forms.

From the above considerations it would seem that *A. africanus* Hewitt, *A. litoralis* Hickman and *A. piscator* Hogg are all synonyms of *A. maritima* Cambridge and that the one species occurs in South Africa, Tasmania, Campbell Island and New Zealand. This wide distribution is correlated with the fact that the spider is adapted to semi-marine conditions. Its nests are often made in cracks and crevices on the seaward faces of rocks and cliffs, which are subjected to wave-action and sea-spray. Young specimens frequently make their retreats amongst drifted sea-weed, which accumulates between high and low tide levels. As the spider feeds largely on marine organisms, such as small crustacea, it could no doubt survive a long sea voyage drifting from South Africa to New Zealand on floating sea-weed.

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Pap. & Proc. Roy. Soc. Tasmania, 1950 (15th December, 1951)

New Phoroncidiinae and the Affinities of the New Zealand spider *Atkinsonia nana* Cambridge

By

V. V. Hickman

Ralston Professor of Biology, University of Tasmania

(Read 14th November, 1950)

With 34 Text Figures

Summary

The following Tasmanian spiders belonging to the sub-family Phoroncidiinae are described as new species: *Trigonobothrys setosus*, *Trigonobothrys aculeatus*, *Ulesanis cygnea* and *Ulesanis trituberculata*. The genus *Atkinsonia* Cambridge is re-established and its taxonomic position discussed. It is transferred to the Phoroncidiinae. A revised description of the New Zealand spider, *Atkinsonia nana* Cambridge, is given and a new species, *Atkinsonia petricola*, from Tasmania described.

Theridiid spiders belonging to the sub-family Phoroncidiinae are characterised by having the spinnerets and anal tubercle surrounded by a chitinous wall. In addition, the abdomen is protected by a dorsal scute or in some cases by a tough leathery integument reinforced with numerous small rounded sclerites. Most of the species are small, being less than 3 mm. in length. Ten genera embracing a total of about 57 species are recorded for the World. Of these species only two, *Ulesanis sextuberculata* Keyserling and *Ulesanis rotunda* (Keyserling), both from Queensland, are listed as occurring in Australia.

In the present paper the New Zealand genus *Atkinsonia* Cambridge which has been regarded as synonymous with *Dipoena* Thorell is re-established and placed in the Phoroncidiinae. In addition, five new species from Tasmania are described as belonging to the sub-family.

In view of the taxonomic importance of the arrangement of the respiratory organs in spiders, these organs have been examined in each of the species studied. In all cases the respiratory system was found to conform to the usual Theridiid pattern, consisting of a pair of book-lungs in the normal position and a tracheal system, which is limited to the abdomen and opens to the exterior by a single median spiracle near the spinnerets.

The species described in the following pages may be distinguished by the appended key.

Key to Species.

1. Front of abdomen with a deep median incision 2
   Front of abdomen without a deep median incision 3
2. Dorsal scute of abdomen without a posterior pair of conical lobes .... *Trigonobothrys setosus* sp. nov.
   Dorsal scute of abdomen with a posterior pair of conical lobes .... *Trigonobothrys aculeatus* sp. nov.
3. Dorsal surface of abdomen raised into conical humps 4
   Dorsal surface of abdomen without conical humps 5

4. Anterior margin of the abdomen forming an angle on each side .... *Ulesanis cygnea* sp. nov.
   Anterior margin of the abdomen not forming an angle on each side .... *Ulesanis trituberculata* sp. nov.
5. Dorsal surface of abdomen convex and clothed with long hairs .... *Atkinsonia nana* Cambridge
   Dorsal surface of abdomen flat and clothed with short hairs .... *Atkinsonia petricola* sp. nov.

Genus **Trigonobothrys** Simon 1888

Trigonobothrys setosus sp. nov.

MALE

	mm.
Total length	1·624
Length of carapace	0·754
Width of carapace	0·638
Length of abdomen	1·102
Width of abdomen	0·928

Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
1	0·4521	0·2329	0·3425	0·2877	0·2603	1·5755
2	0·4521	0·2329	0·3151	0·2603	0·2603	1·5207
3	0·4110	0·2329	0·3014	0·2466	0·2877	1·4796
4	0·5206	0·3014	0·4110	0·3288	0·3151	1·8769
Palp	0·2740	0·1096	0·0822	—	0·3425	0·8083

Colour (in alcohol). Cephalothorax and appendages golden brown. Legs banded with dark-brown round the distal half of each femur, the base and middle of each tibia and the base of each metatarsus. The bands are more pronounced on the ventral than on the dorsal side. Abdomen golden brown above with three dark spots on each side and five in the middle. In some specimens the five middle spots merge into a central brown patch. The ventral surface and sides of the abdomen are golden brown.

Carapace. Slightly longer than wide, strongly convex, rounded at the sides. Head region narrow, high and projecting over the clypeus (fig. 1). Thoracic groove deep and longitudinal. Cervical groove well defined. Radial grooves strongly marked and short, not reaching half way to the margin. Coarse erect bristles are present on the cephalic part and a few hairs in the ocular area. On the clypeus, round the margin of the carapace, between the radial grooves and behind the thoracic groove are a few minute hairs mounted on small granules.

Eyes. Eight, arranged in two rows. Viewed from above the front row appears strongly recurved and the posterior row very slightly recurved, almost straight. Ratio of eyes AME : ALE : PME : PLE = 6 : 5 : 5 : 5. AME are mounted on a black tubercle and separated from each other by 5/6 of their diameter. They almost touch ALE. The lateral eyes are contiguous. PME separated from each other by once their diameter and from PLE by 3/5 of their diameter. The median ocular area is wider in front than behind in ratio 15 : 14. Its length is about equal to its posterior width. The height of the clypeus is about four and a half times the diameter of AME.

Chelicerae. Small, conical, clothed with a few stiff hairs in front. Inner side oblique, without teeth but with a row of five setae. Fang not strongly curved (fig. 2).

Maxillae. Somewhat triangular, strongly converging in front of labium. Provided with a scopula at the apex and serrula on front margin.

Labium. Wider than long. Rounded in front and at the base.

Sternum. Shield-shape and as wide as long. Excavated in front round base of labium. Truncate posteriorly between the fourth coxae, which are widely separated. Surface slightly convex and lightly clothed with hairs arising from small tubercles. Margin rebordered.

Legs. 4.1.2.3. The first three pairs almost equal in length. The first and second tarsi and metatarsi stouter than the third and fourth. The first tarsi have a dense clothing of hairs on the ventral side near the apex. Elsewhere the clothing of hairs is light. On the dorsal side of each patella and tibia there are 1 — 1 stout bristles. There are three trichobothria on each tibia and one on the distal half of each metatarsus. A drum is present on the basal quarter of each tarsus. The upper tarsal claws are similar and provided with a single tooth near the apex. The lower claw is small, strongly bent and has one minute tooth. The comb on the fourth tarsi is composed of 5 or 6 barbed setae.

Palpi. Tarsus large and spoon-shaped. Tibia cup-shaped, narrow at the base, provided with a circlet of hairs and one trichobothrium. Patella small. No apophyses on any of the segments. The form of the genital bulb is shown in fig. 3. The embolus arises near the base of the cymbium, curves upwards and runs round the upper margin of the alveolus to end in a point immediately below the apex.

Abdomen. Somewhat heart-shaped (fig. 4). The dorsal surface is almost completely covered by a hard chitinous shield, only the tip of the abdomen and spinnerets being left uncovered. The front margin has a deep cleft in the middle, thus forming a rounded lobe on each side. These lobes are provided with erect spine-like setae, each of which arises from a small tubercle. Posteriorly the spine-like setae are replaced by finer setae and hairs. The dorsal shield curves downwards round the lateral margins so as partly to cover the sides of the abdomen. In front the ventral surface is covered by an epigastric scute, which incorporates a pair of elongated oval pulmonary sclerites. On each side the posterior margin of the scute is produced backward forming a notch in which lies the pulmonary spiracle. The posterior half of the ventral surface is partly covered by a rectangular ventral scute. Between this and the epigastric scute are several smaller rounded sclerites (fig. 5). The spinnerettes and anal tubercle are surrounded by a chitinous ring. On the ventral surface of the ring and near its posterior margin is a median transverse slit, which opens into the tracheal spiracle. Six spinnerets are present, the anterior pair being the largest. A colulus is absent.

FEMALE

	mm.
Total length	2·030
Length of carapace	0·754
Width of carapace	0·667
Length of abdomen	1·450
Width of abdomen	1·160

Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
1	0·5617	0·2603	0·2836	0·3425	0·3425	1·8906
2	0·5069	0·2740	0·3014	0·3014	0·3288	1·7125
3	0·4932	0·2740	0·3425	0·3014	0·3562	1·7673
4	0·6302	0·3699	0·4795	0·3973	0·3973	2·2742
Palp	0·1918	0·0959	0·1370	—	0·2192	0·6439

Colour (in alcohol). Golden brown like that of the male, but the head region is somewhat darker and the dorsal scute of the abdomen has a longitudinal brown area extending from the anterior cleft to the posterior margin. This merges with the five dark brown spots in the middle of the scute.

Carapace. Resembles that of the male but lacks the strongly marked radial grooves.

Eyes. Equal in size. AME separated from each other by once their diameter and from ALE by 1/5 their diameter. Lateral eyes contiguous. PME separated from each other by once their diameter. Median ocular area almost square.

Chelicerae, maxillae, labium and *sternum* as described for the male.

Legs. 4.1.3.2. Trichobothria, setae, claws and tarsal drum as in the male.

Palpi. The tarsus ends in a wide claw, which is somewhat spatulate in shape and is armed in front with 7 teeth (fig. 6). The claw is not unlike that of *Hadrotarsus ornatus* Hickman. No drum is present. The hairs on the under side of the segment are barbed. The tibia has a single trichobothrium.

Abdomen. Resembles that of the male, but the dorsal scute is relatively smaller and covers only the anterior two-thirds of the dorsal surface. The epigastric scute on the ventral side is also smaller than in the male and does not incorporate the pulmonary sclerites on either side. There is also no ventral scute behind the epigastric furrow but several small sclerites are present (fig. 7). The epigynum occupies a large part of the epigastric scute. It has the form shown in fig. 8.

Locality. The type specimens were collected on the Domain, Hobart. The female was found 1st June, 1944, and the male in July, 1948. The spider also occurs at Trevallyn, Launceston. It is generally taken in grass tussocks or on the under side of stones.

Trigonobothrys aculeatus sp. nov.

MALE

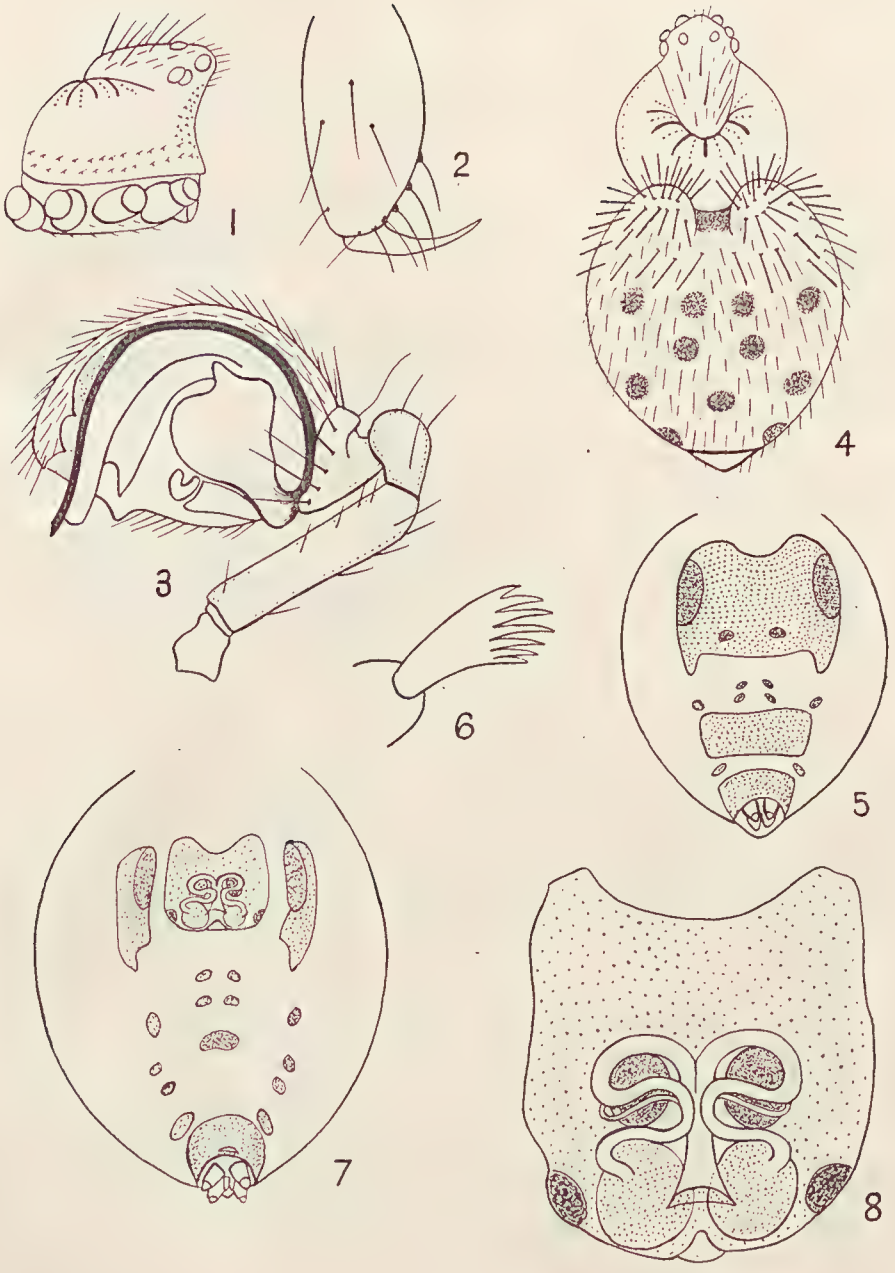
	mm.
Total length	1·914
Length of carapace	0·696
Width of carapace	0·696
Length of abdomen	1·276
Width of abdomen	1·044

Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
1	0·5480	0·2740	0·4110	0·3973	0·2877	2·1180
2	0·5069	0·2603	0·3973	0·3699	0·3151	1·8495
3	0·4795	0·2466	0·3288	0·3425	0·3288	1·7262
4	0·6165	0·3151	0·4795	0·4521	0·3425	2·2057
Palp	0·3562	0·1370	0·0685	—	0·5069	1·0686

Colour (in alcohol). Carapace, labium and sternum chocolate-brown. Legs yellowish banded with dark-brown. Chelicerae and maxillae yellowish-brown. Dorsal scute of abdomen dark chocolate-brown with a pair of narrow oblique golden-yellow stripes near the middle. In front of and behind these stripes are a few irregular yellowish spots. Sides of abdomen brown marked with cream. Ventral surface brown, the scutes being dark-brown. The spinnerets yellow.

Carapace. As wide as long. Rounded at the sides. Strongly convex and high. The head region forms a narrow rounded prominence, which projects over the clypeus (fig. 9). The dorsal surface somewhat granular and rugose but becoming smooth at the sides. Thoracic groove deep and longitudinal. Cervical and radial grooves deep and short. A few erect setae on the head region. Short hairs on the clypeus and dorsal surface of the carapace.

Eyes. Eight, arranged in two rows. Viewed from above the front row is strongly recurved and the posterior row almost straight. Ratio of eyes AME : ALE : PME : PLE = 7 : 5 : 5 : 5. AME are separated from each other by 4/7 of their diameter and from ALE by 1/7 of their diameter. The lateral eyes



Trigonobcthrys setosus sp. nov. Fig. 1: Carapace of male. Fig. 2: Chelicera of male. Fig. 3 : Male palp. Fig. 4: Carapace and abdomen of male. Fig. 5: Scutes on ventral surface of abdomen of male. Fig. 6: Claw of female palp. Fig. 7: Scutes on ventral surface of abdomen of female. Fig. 8: Epigastric scute and epigynum of female.

are contiguous. PME are separated from each other and from PLE by about once their diameter. The median ocular area is wider in front than behind in ratio 17 : 14. Its length is equal to its width in front. The height of the clypeus is nearly five times the diameter of AME.

Chelicerae. Small and conical, clothed with a few hairs. Devoid of teeth and scopula but with a row of five stiff hairs along the oblique inner margin. Fang not strongly curved.

Maxillae. Converging to form an arch-like curve in front of labium. A scopula at the apex and a long well developed serrula on the curved anterior margin.

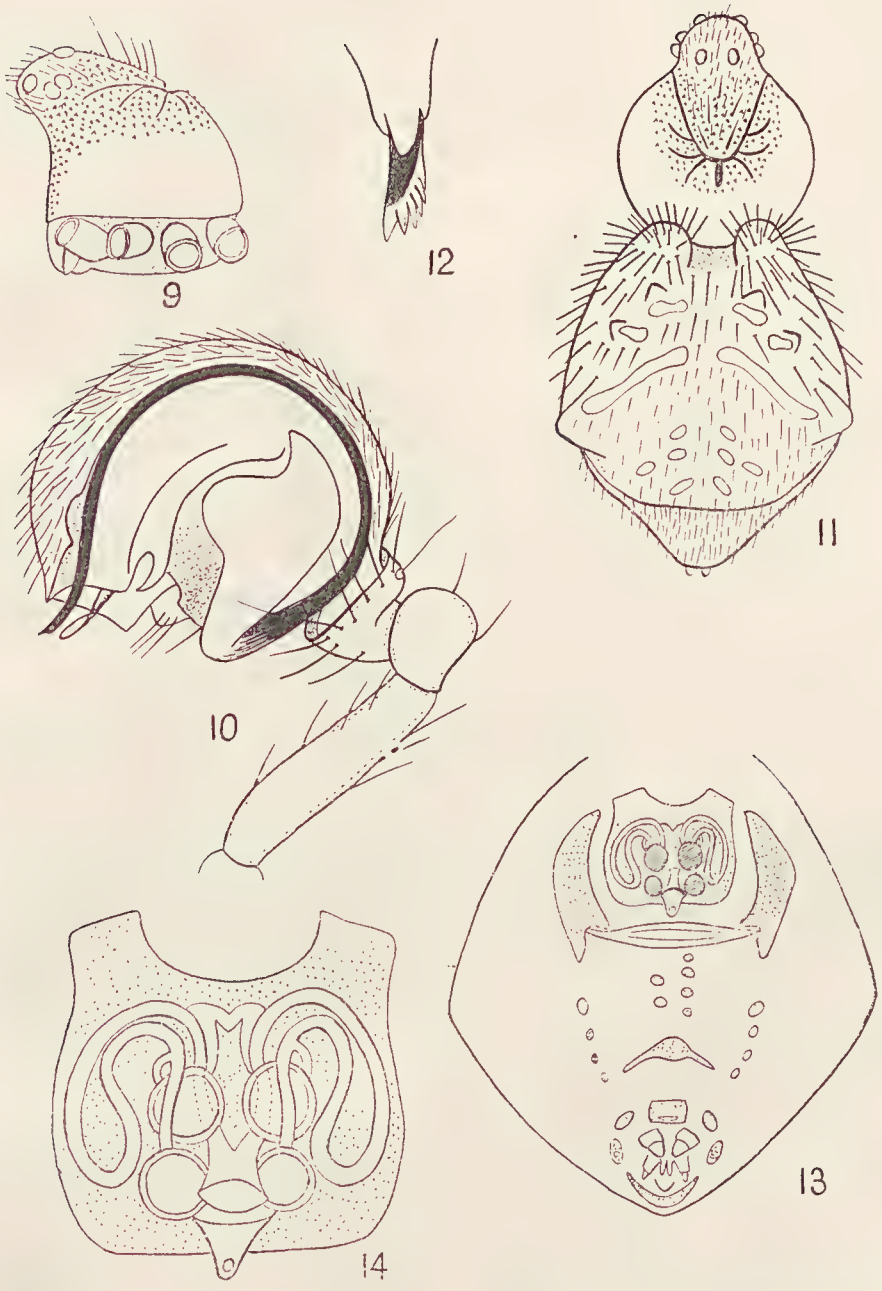
Labium. Rounded in front and at the base. Wider than long. Clothed with a few hairs.

Sternum. Shield-shaped, as wide as long and strongly convex. Truncate between the fourth coxae. Front margin excavated round base of labium. Lateral margins forming pointed projections between the bases of the coxae. Surface lightly clothed with hairs.

Legs. 4.1.2.3. Short and moderately stout. Lightly clothed with barbed hairs. On the under side of the first tarsi the hairs form a dense group near the apex. Metatarsi longer than tarsi. One basal and one apical bristle on each patella and 1 — 1 bristles on the dorsal side of each tibia. A single trichobothrium in the apical quarter of each metatarsus and four on each tibia. A small drum in the basal quarter of each tarsus. Three tarsal claws are present. The upper claws are similar and provided with a small tooth near the apex. The lower claw is strongly bent and also has one small tooth. The comb on the fourth tarsi is formed by a row of five barbed setae.

Palpi. Tarsal segment large and spoon-shaped (fig. 10). Tibia and patella short and without apophyses. A single trichobothrium is present on the tibia. Femur shorter than tarsus. The alveolus is large and occupies almost the whole of one side of the tarsus. The embolus arises from the genital bulb a short distance from the base and curves upward round the dorsal margin of the alveolus to end near the apex of the segment. The structure of the palp closely resembles that of the preceding species, *T. setosus*, but the tarsus is relatively larger and more rounded in outline and the origin of the embolus is not so close to the base of the segment.

Abdomen. Viewed from above the outline is somewhat rhomboidal, narrowed in front and pointed behind (fig. 11). The anterior three-quarters of the dorsal surface is covered by a hard scute, which is deeply incised on the front margin. Stiff spine-like setae are present on the front half of the dorsal surface and are especially prominent on each side of the median cleft. Two conical lobes, one on each side, arise near the postero-lateral angles of the dorsal scute. Between these lobes and the front of the abdomen are two pairs of small inconspicuous lobes. These are not readily seen from above but are clearly visible from the side. The lateral margins of the dorsal scute are bent downward so as partly to cover the sides of the abdomen. In front of the epigastric furrow the ventral surface is protected by a large epigastric scute, which incorporates the lung covers. The posterior lateral angles of the scute extend backwards forming a notch on each side to accommodate the pulmonary spiracle. Behind the epigastric scute is a narrow transverse sclerite bounding the posterior margin of the epigastric furrow. Immediately in front of the spinnerets is a small ventral sclerite, which extends upwards



Trigonobothrys aculeatus sp. nov. Fig. 9: Carapace of male. Fig 10: Male palp. Fig. 11: Carapace and abdomen of male. Fig. 12: Claw of female palp. Fig. 13: Scutes on ventral surface of abdomen of female. Fig. 14: Epigastric scute and epigynum of female.

on each side forming portion of the chitinous ring round the spinnerets. The ring is completed by a dorsal sclerite which extends downwards on each side to meet the ventral sclerite but does not fuse with it. Between the epigastric furrow and the spinnerets are four longitudinal rows of small rounded sclerites, two rows in the middle and one on each side. The tracheal spiracle is single and median. It is situated on the ventral sclerite immediately in front of the spinnerets. Six spinnerets are present but a colulus is absent.

FEMALE

	mm.
Total length	2·030
Length of carapace	0·754
Width of carapace	0·696
Length of abdomen	1·276
Width of abdomen	1·276

Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
1	0·5891	0·2740	0·4110	0·3836	0·2740	1·9317
2	0·5480	0·2603	0·3562	0·3562	0·2877	1·8084
3	0·5069	0·2603	0·3151	0·3425	0·2877	1·7125
4	0·6850	0·3425	0·4795	0·4795	0·3014	2·2879
Palp	0·2055	0·0685	0·1370	—	0·2466	0·6576

Coloration and general appearance as in the male.

Carapace. Not so strongly convex as in the male. Nor are the cervical and radial grooves so deeply marked.

Eyes, chelicerae, maxillae, labium, sternum and *legs* as in the male.

Palpi. Small. Tarsus slightly longer than femur. Two bristles on dorsal side of patella. A single trichobothrium on basal half of tibia. Tarsal claw broad with five teeth on the prolateral (inner) margin (fig. 12). Tarsal drum absent.

Abdomen. The dorsal scute resembles that of the male in form and size. The epigastric scute, however, is smaller and does not incorporate the elongated lung covers situated on either side (fig. 13). The ventral scute is small and somewhat crescentic. The chitinous ring round the spinnerets is poorly developed and is composed of separate sclerites. Between the ventral scute and the epigastric furrow are four longitudinal rows of sclerites as in the male. Different specimens often show variations in the number of these sclerites and also in the extent to which the ventral scute and chitinous ring round the spinnerets are developed. The epigynum occupies almost the whole of the epigastric scute. In transparent preparations it has the form shown in fig. 14.

Locality. The type specimens, male and female, were collected on gorse at the Punch Bowl, Launceston, 23rd May, 1930. The species also occurs at East Risdon. It is usually taken on low shrubs and grass tussocks but is sometimes found on the under side of stones.

Trigonobothrys aculeatus is readily distinguished from the preceding species, *T. setosus*, by the form of the abdomen. Both these species differ from *T. aheneus* Dyal (1935, p. 162), found in the Panjab, in having the front of the abdomen incised. They may also be distinguished from the West African species, *T. molle* Simon (1903, p. 75), in possessing a hard dorsal scute on the abdomen, and from *T. excisus* Simon (1888, p. 231), found in Madagascar, in the shape and nature of the dorsal scute.

Genus **Ulesanis** L. Koch, 1872

Ulesanis cygnea sp. nov.

MALE

	mm.
Total length	1·7980
Length of carapace	0·5480
Width of carapace	0·6576
Length of abdomen	1·4385
Width of abdomen	1·1234

Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
1	0·4795	0·2329	0·2740	0·2329	0·2466	1·4659
2	0·4110	0·2192	0·2329	0·2055	0·2603	1·3289
3	0·3699	0·2055	0·2192	0·1918	0·2466	1·2330
4	0·5206	0·2466	0·3288	0·2603	0·2877	1·6440
Palp	0·3699	0·2055	0·0822	—	0·4932	1·1508

Colour (in alcohol). Carapace dark-brown, almost black, the median thoracic region, which is covered by the front of the abdomen, being paler. Legs and palpi yellowish, banded with dark-brown. Sternum, maxillae and labium dark-brown. Abdomen dark-brown with yellowish markings, especially at the antero-lateral angles and on the sides. A rectangular yellow area on ventral surface in front of spinnerets. The dark-brown and yellow pigmentation varies in different specimens. In some cases dark-brown, in others yellow predominates.

Carapace. Short, slightly wider than long, narrowed in front, rounded at the sides and excavated on the posterior margin above the pedicle. The cephalic region is extended upwards into a long curved neck-like projection, which bends forward and overhangs the front margin. The length of this projection is not included in the measurement of the length of the carapace given above. The surface of the carapace is smooth, shining and hairless, except on the neck-like cephalic part, where a few hairs are present (fig. 15).

Eyes. Eight. Ratio of eyes AME : ALE : PME : PLE = 10 : 7 : 8 : 7. The AME are situated almost at the end of the cephalic projection and are separated from each other by 6/5 of their diameter. The lateral eyes are contiguous, ALE forming a straight transverse line with PME, from which they are separated by 1/2 the diameter of AME. The PME are separated from each other by 3/8 of their diameter and from AME by 3/2 times the diameter of AME. The median ocular area is wider in front than behind in ratio 11 : 8 and its length is greater than its anterior width in ratio 15 : 11.

Chelicerae. Small and conical. The furrow is short and transverse with a single blunt tooth on the promargin. Scopula absent. Fang stout and curved. In front the base of the paturon is extended upward under the clypeus as a long pointed process (fig. 16).

Maxillae. Converging in front of labium. Provided with a scopula at the apex and a serrula on the front margin. Clothed with a few hairs.

Labium. Triangular. Almost twice as wide as it is long. Furnished with a few hairs.

Sternum. Heart-shaped, longer than wide in ratio 10 : 9, flat, rebordered, with pointed marginal processes extending between the bases of the coxae. Posterior end truncate, the fourth coxae being widely separated. A few scattered hairs on the surface, which is slightly pitted and rugose. Below the lateral margins of the carapace the epimera are fused together to form a continuous band on each side.

Legs. 4.1.2.3. Short and stout. Lightly clothed with hairs. Spines and scopulae absent. Three trichobothria on basal half of first and second tibia and four on the third and fourth tibia; one an the basal half of each metatarsus. Tarsi longer than metatarsi. Each tarsus has a drum situated in the basal quarter. Hairs on the tarsi are barbed. A tarsal comb formed of about six barbed hairs is present on the fourth tarsi. Three tarsal claws and setae forming accessory claws are present. The upper claws are similar and provided with three small teeth, which decrease in size towards the base. The lower claw is bent at a right angle and has one large and one small tooth.

Palpi. Tarsus large, narrow and longer than femur. The apex forms a hard black point devoid of hairs. The outer margin of the cymbium in the apical third gives rise to a hook-like process clothed with a few hairs and ending in a short curved spine. The embolus (fig. 17) arises on the outer side of the genital bulb. It curves upward, backward and downward passing under the base of the tarsus to the inner side, where it curves upward, forward and downward to end near the apex. On the inner side it is covered and protected by a transparent chitinous plate. The tibia is very short. It is provided with a circlet of hairs and a single trichobothrium.

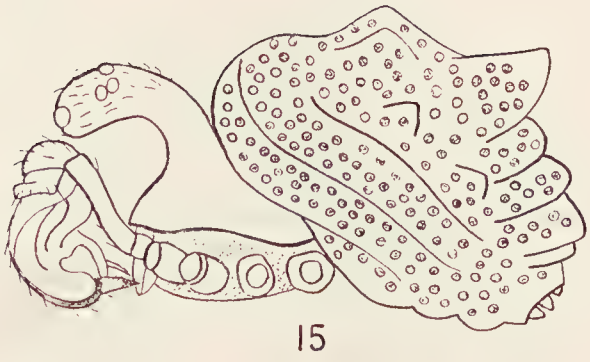
Abdomen. The front of the abdomen overhangs the carapace as far forward as the base of the neck-like cephalic region. The integument is tough and leathery, being studded with numerous small oval setigerous sclerites. Across the middle of the dorsal surface is a recurved row of four conical humps, the median pair being larger than the outer pair. Behind these is a transverse row of three similar humps, the middle one being the largest on the abdomen. Immediately in front of the row of humps across the middle of the abdomen is a transverse row of six oval sclerites, which do not carry hairs. A second row of five similar sclerites is situated immediately in front of the posterior row of humps. The middle sclerite in this latter row being composed of two fused together. At the sides of the abdomen and above the spinnerets the integument forms a series of folds, which are reinforced with elongate chitinous sclerites. Posteriorly these form two transverse bars below the large conical hump. On the ventral surface there is an epigastric scute, which extends forward on each side of the pedicle but does not surround it. The pulmonary spiracles are situated, one on each side, in a notch on the posterior margin of the scute. The spinnerets, colulus and anal tubercle are surrounded by a wide chitinous ring. The tracheal spiracle is in the form of a median transverse slit on the ventral surface of the ring. The anterior spinnerets are larger than the others. The colulus is small and tipped with three setae.

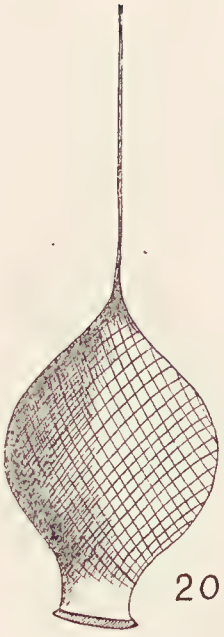
FEMALE

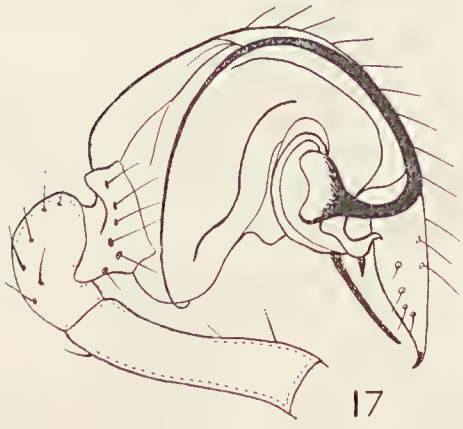
	mm.
Total length	2·320
Length of carapace	0·808
Width of carapace	0·808
Length of abdomen	2·088
Width of abdomen	2·494

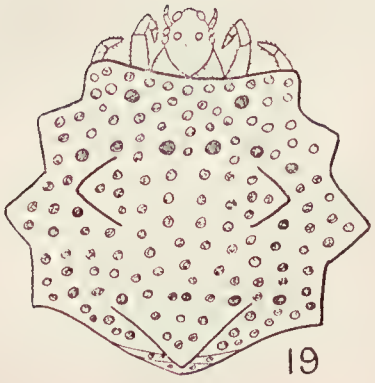
Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
1	0·5480	0·2877	0·2877	0·2603	0·2466	1·6303
2	0·4795	0·2740	0·2603	0·2329	0·2603	1·5070
3	0·4110	0·2740	0·2877	0·2466	0·2740	1·4933
4	0·6987	0·3151	0·4658	0·3562	0·3151	2·1509
Palp	0·2055	0·0959	0·1233	—	0·2055	0·6302

Colour (in alcohol). As in the male but some specimens are almost entirely black.









Ulcsanis cygnea sp. nov. Fig. 15: Lateral view of male. Fig. 16: Chelicera of male. Fig. 17: Male palp. Fig. 18: Carapace of female. Fig. 19: Dorsal view of female. Fig. 20: Egg-sac.

Carapace. Rounded at the sides, narrow in front, convex and as wide as long. The cephalic region is elevated and slopes forward (fig. 18). Anteriorly it projects over the clypeus, but does not form a long neck-like structure as in the male.

Eyes. Eight. Ratio of eyes AME : ALE : PME : PLE = 7 : 5 : 6 : 6. The AME separated from each other and from ALE by 5/7 of their diameter. Lateral eyes contiguous. PME separated from each other and from PLE by 5/6 of their diameter. Median ocular area rectangular, longer than wide in ratio 18 : 17. Clypeus high and curved forward. Cephalic region lightly clothed with hair. Thoracic region smooth, shining and devoid of hair.

Chelicerae, maxillae, labium, sternum and *legs* as in male.

Palpi. Small. Tarsal segment without a drum. Clothed with barbed hairs. Claw absent. A single trichobothrium is present on the tibia.

Abdomen. Wider than long. When viewed from above it appears polygonal in outline (fig. 19). The front margin is almost straight. The anterior part of the abdomen overhangs the cephalothorax reaching as far forward as the head region. The integument is tough and leathery being strengthened with numerous rounded sclerites. Projecting on each side are four angular lobes or humps. Near the middle of the dorsal surface is a pair of large conical humps and behind these near the posterior margin is a single large median hump. The sides of the abdomen exhibit a series of folds as in the male. The ventral surface has a small epigastric scute, on each side of which is a narrow pulmonary plate. In surface view the epigynum has the form of a small median conical lobe on the posterior margin of the epigastric scute. Spinnerets, colulus and anal tubercle are surrounded by a chitinous ring.

Locality. The type specimens, male and female, were found together with other adult and immature forms on the under side of stones at Fern Tree, Mt. Wellington, Tasmania, on 25th August, 1947.

Habits and *Egg-sac.* The spider spins a small irregular web on the under side of stones. The egg-sac, which is pear-shaped, is made of golden brown silk (fig. 20). It is suspended from the under surface of a stone by a long thread composed of several strands. The wall of the egg-sac is tough and parchment like, but at the bottom there is a short tubular opening provided with a flange and closed with a diaphragm of soft silk, through which the young spiderlings make their escape. The sac measures 3·19 mm. long and 2·32 mm. in greatest diameter. The thread by which it is suspended varies in length from 6 mm. to 11 mm. One sac was found to contain 22 eggs. Each egg measures about 0·580 mm. in diameter. Two or three egg-sacs are sometimes found suspended close together.

Ulesanis trituberculata sp. nov.

MALE

	mm.
Total length	1·2056
Length of carapace	0·4658
Width of carapace	0·4795
Length of abdomen	1·0960
Width of abdomen	0·8768
Height of abdomen	1·0960

Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
1	0·3836	0·1918	0·2055	0·1918	0·2055	1·1782
2	0·3562	0·1918	0·1918	0·1781	0·2055	1·1234
3	0·2740	0·1644	0·1781	0·1507	0·2192	0·9864
4	0·4247	0·2192	0·2740	0·2055	0·2466	1·3700
Palp	0·3014	0·1507	0·0685	--	0·2740	0·7946

Colour (in alcohol). Cephalothorax and appendages golden brown. Abdomen yellowish with brown markings.

Carapace. Slightly wider than long. Narrowed in front and rounded at the sides. Head region high and produced into a neck-like projection, which is curved forward over the anterior margin (fig. 21). Clypeus high. Surface of carapace smooth, except the head region which is clothed with short hairs mounted on small granules. The epimera fused into a continuous band on each side below the margin of the carapace.

Eyes. Eight, carried on the neck-like projection, and arranged in two rows. Viewed from above the front row appears strongly recurved and the posterior row almost straight. Ratio of eyes AME : ALE : PME : PLE = 6 : 4 : 5 : 5. The AME are separated from each other by 5/6 of their diameter and from ALE by 1/2 of their diameter. The lateral eyes are contiguous. PME are separated from each other by once their diameter and from PLE by 3/5 of their diameter. The median ocular area is rectangular and longer than wide in ratio 17 : 15.

Chelicerae. Small, conical, parallel. Furrow transverse a single tooth on promargin near basal end of furrow. Fang short curved and stout. Scopula absent. In front the basal end of the paturon is produced upward under the clypeus as a long sharp process (fig. 22).

Maxillae. Triangular, converging in front of labium. A scopula at apex and a serrula on the front margin.

Labium. Triangular, wider than long in ratio 7 : 6 and clothed with about seven hairs.

Sternum. Heart-shaped, as wide as long, truncate posteriorly between the fourth coxae, which are widely separated. Surface clothed with a few hairs and not pitted.

Legs. 4.1.2.3. Short and stout, lightly clothed with hairs but devoid of spines. Tarsi longer than metatarsi. Three trichobothria on the basal half the first and second tibia and four on the third and fourth tibia, one on the basal half of each metatarsus. A drum is present on the basal quarter of each tarsus. Three tarsal claws and setae modified as accessory claws are present. The upper claws are similar and provided with three teeth. The lower claw is strongly bent and has two teeth. The comb on the fourth tarsi is formed by a row of five barbed setae.

Palpi. Tarsus shorter than femur, and produced into a hard point, devoid of hairs, at the apex. The retromargin of the cymbium forms a hook-like projection near the apex (fig. 23). Distally the genital bulb gives rise to a stout curved apophysis, the tip of which is near the apex of the tarsus and is provided with a dense group of small teeth on one side. The embolus is difficult to see and its course has not been followed. Tibia very short and cup-like. It has no apophyses but carries a single trichobothrium and a circlet of hairs.

Abdomen. As high as it is long. In front it overhangs the carapace as far forward as the head region. Arising from the middle of the dorsal surface are two conical humps situated side by side, with a third slightly larger hump in a median position close behind them. The integument is tough and leathery. It has numerous small oval sclerites, which give to it a pitted appearance. Immediately in front of the middle pair of humps is a transverse row of six larger sclerites, and between the paired humps and the posterior median hump is a similar row of five sclerites. At the sides of the abdomen are three longitudinal folds, which are continuous above the spinnerets. In the grooves between the folds are narrow

chitinous bars. On the ventral side is a well developed epigastric scute, which is fused with the pulmonary plates on either side and also with a small crescentic plate above the petiolus. The pulmonary spiracles open in a notch on each side of the posterior margin of the epigastric scute. Behind the posterior lateral angles of the scute are two rounded sclerites, one on each side. The spinnerets, colulus and anal tubercle are surrounded by a thick annular chitinous tube, on the ventral surface of which is a short median transverse slit, which forms the opening of the tracheal spiracle. The colulus is small and furnished with three small hairs. There are six spinnerets, the anterior pair being the largest.

FEMALE

	mm.
Total length	1·740
Length of carapace	0·696
Width of carapace	0·580
Length of abdomen	1·508
Width of abdomen	1·276

Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
1	0·4110	0·2192	0·2055	0·1781	0·2329	1·2467
2	0·3699	0·2055	0·1918	0·1781	0·2466	1·1919
3	0·3151	0·1918	0·2055	0·1918	0·2466	1·1508
4	0·5343	0·2466	0·3425	0·2605	0·2877	1·6714
Palp	0·1507	0·0959	0·0822	—	0·1644	0·4932

Colour (in alcohol). As in the male.

Carapace. Resembles that of the male except that the cephalic region is not elevated to the same extent (fig. 24).

Eyes. Eight, arranged in two rows. Viewed from above the front row appears strongly recurved and the posterior row almost straight. Ratio of eyes AME : ALE : PME : PLE = 7 : 5 : 5 : 6. The AME are separated from each other and from ALE by 5/7 of their diameter. Lateral eyes contiguous. PME separated from each other by 6/5 of their diameter and from PLE by once their diameter. Median ocular area wider behind than in front in ratio 17 : 16. Its length is greater than its posterior width in ratio 20 : 17.

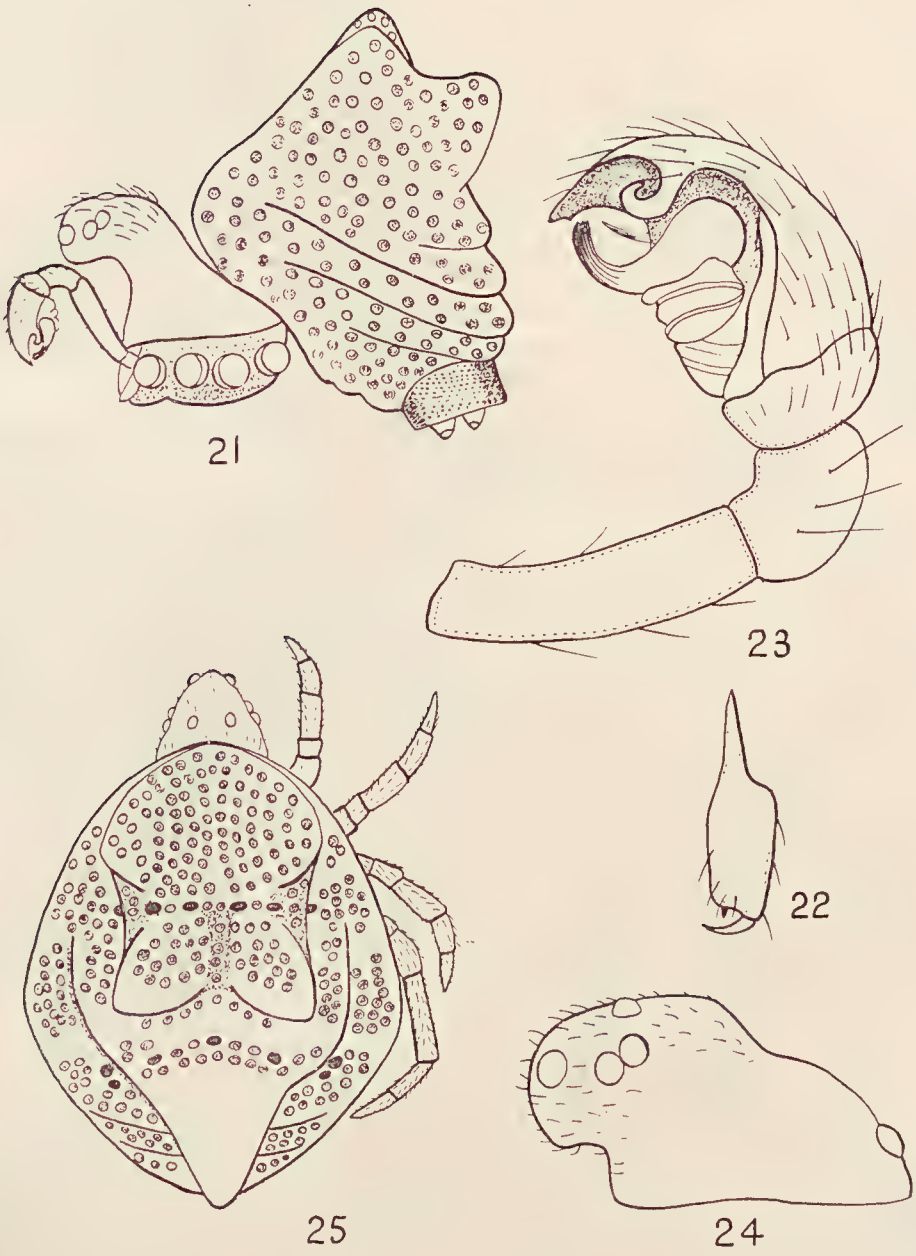
Chelicerae, maxillae, labium, sternum and *legs* as in the male.

Palpi. Small, lightly clothed with hairs, those on the tarsus being barbed. A single trichobothrium on the tibia and a drum on the apical half of the tarsus. No tarsal claw is present.

Abdomen. When viewed from above somewhat rhomboidal in outline. Not as high as in the male. The dorsal surface is raised into three large conical humps, which are situated in a similar position to those of the male. In addition to these there are two smaller lobes, one on each side, nearer the front of the abdomen (fig. 25). The integument is studded with small rounded sclerites. The epigastric scute is not fused with the pulmonary plates nor with the crescent-shaped sclerite above the petiolus. Spinnerets as in the male. The epigynum occupies the middle of the epigastric scute. It is a somewhat rectangular plate having a median depression, which leads into a crescent-shaped aperture anteriorly.

Locality. The type specimens, male and female were collected in gorse at the Punch Bowl, Launceston, Tasmania, 23rd May, 1930. Other specimens have been taken in low shrubs at Lenah Valley, and in grass tussocks at East Risdon.

Ulesanis trituberculata and *U. cygnea* differ from each other in the form of the abdomen. The presence of a large posterior median hump distinguishes both species from the two Queensland forms, *U. sextuberculata* Keys. and *U. rotunda* (Keys.), and from the three New Zealand species *U. excussa* (Urquhart), *U. lacunosa* (Urquhart) and *U. quadrata* (Cambridge). The Fijian spider, *U. personata* L. Koch differs from the two Tasmanian species in having a strongly pitted carapace.



Ulesanis trituberculata sp. nov. Fig. 21: Lateral view of male. Fig. 22: Chelicera of male. Fig. 23: Male palp. Fig. 24: Carapace of female. Fig. 25: Dorsal view of female.

Genus **Atkinsonia** *Cambridge* 1879

The genus *Atkinsonia* was founded on the characters of a small New Zealand spider, which Cambridge described under the name of *Atkinsonia nana*. The definition of the genus and the description of the species are adequate for the identification of the spider but not in sufficient detail to indicate the true affinities of the species. Simon (1894, p. 546) regarded the spider as belonging to his group Theridieae, whilst Dalmas (1917, p. 358) and Bryant (1933, p. 10) have abandoned the genus *Atkinsonia* and have placed the spider in the genus *Dipoena* Thorell, which belongs to Simon's group Dipoeneae.

Through the courtesy of Mr. C. L. Wilton I have received from Mangarei, New Zealand, two adult males and one adult female of *Atkinsonia nana*. An examination of these specimens shows quite clearly that the spider is much more closely related to genera in the sub-family Phoroncidiinae than it is to the genus *Dipoena*. Several features mentioned by Cambridge (1879, p. 691) suggested that this might be the case. For example, he describes the cuticle of the abdomen as being 'somewhat coriaceous, thickly covered with pock-like markings' and states that 'the spinners are enclosed within a kind of sheath-like circular border'. These features are not possessed by members of the genus *Dipoena* but are characteristic of genera belonging to the Phoroncidiinae.

It seems necessary, therefore, to re-establish the genus *Atkinsonia*, to amplify the definition which Cambridge has given and to redescribe the species, *Atkinsonia nana*, in greater detail.

Definition of the Genus. Cephalothorax short and convex. Front of head region projecting over the clypeus, which is high. Eight eyes in two rows. Front row strongly recurved, posterior row almost straight. Lateral eyes contiguous. Median ocular area nearly square. Legs short and slender, 4.1.2.3. Tarsi longer than metatarsi. Chelicerae small and short, their length being less than the height of the clypeus. Tarsus of male palp produced into a narrow conical point at apex. Palp of female ending in a broad spatulate toothed claw. Front of abdomen projecting over base of carapace. Cuticle of abdomen coriaceous. Epigastric scute well developed. Spinnerets and anal tubercle surrounded by a chitinous ring.

Atkinsonia nana Cambridge

	mm.
Total length	1·5660
Length of carapace	0·5800
Width of carapace	0·5754
Length of abdomen	1·1600
Width of abdomen	0·9316

Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
1	0·4110	0·2055	0·2740	0·2192	0·2740	1·3837
2	0·3973	0·2055	0·2466	0·2192	0·3014	1·3700
3	0·3699	0·2055	0·2603	0·2192	0·3151	1·3700
4	0·4110	0·2191	0·3425	0·2466	0·3425	1·5618
Palp	0·1507	0·0822	0·0822	—	0·2603	0·5754

Colour (in alcohol). Carapace, palpi, chelicerae, legs, maxillae and sternum reddish brown, the legs having dark infuscation underneath. Head region with a median brown area. Dorsal surface of abdomen yellowish with a longitudinal brown area in the middle and on each side. Ventral surface yellowish brown with reddish brown epigastric scute and sclerites.

Carapace. Slightly longer than wide. Narrowed in front, rounded at the sides. Head region high and projecting over the clypeus in front. The height of the clypeus is greater than the length of the chelicerae. Surface lightly clothed with hairs. Four long setae in a transverse row on posterior part of head region.

Eyes. Eight, arranged in two rows, which occupy the full width of the carapace in front. Viewed from above the anterior row is recurved and the posterior row is straight. Ratio of eyes AME : ALE : PME : PLE = 4 : 4 : 6 : 4. The AME are separated from each other by about once their diameter and from ALE by 1/4 of their diameter. PME are separated from each other and from PLE by 1/2 their diameter. The lateral eyes are contiguous, the median ocular area is slightly wider behind than in front in ratio 13 : 12, and is longer than its posterior width in ratio 14 : 13. The eyes are surrounded by black rims.

Chelicerae. Small and conical. Teeth and scopula absent. Fang long, slender and curved (fig. 26). In a position of rest the right and left fangs lie transversely, one behind the other.

Maxillae. Triangular, converging in front of labium, provided with a scopula at the apex and a serrula on front margin.

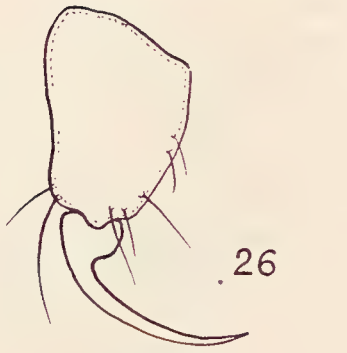
Labium. Triangular, wider than long, rounded at the base, clothed with about ten hairs.

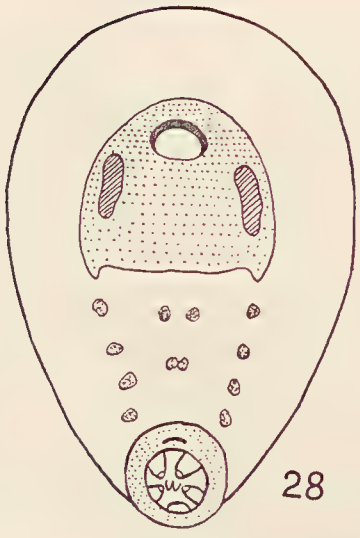
Sternum. Shield-shape, wider than long in ratio 27 : 25. Truncate posteriorly between the fourth coxae, which are widely separated. Front margin excavated round the base of labium. Surface convex, lightly clothed with long hairs.

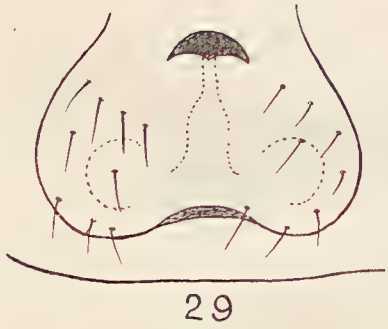
Legs. 4.1.2.3. Lightly clothed with hairs. Spines absent. One basal and one apical bristle on dorsal side of each patella and 1 — 1 bristles on dorsal side of each tibia. Two trichobothria on first and second tibia, three on the third and four on the fourth; one on each metatarsus. A drum is present near the base of each tarsus. Three tarsal claws. Upper claws of the first, second and fourth legs have five prolateral teeth and a single retrolateral tooth, those of the third leg have five prolateral teeth and one retrolateral tooth on the pro-claw and one prolateral tooth and five retrolateral teeth on the retro-claw. The lower claw is very small and strongly bent. Tarsi are longer than metatarsi.

Palpi. The tarsus ends in a short conical projection which terminates in a hard point. The alveolus is oval in outline. Its apical margin is thickly chitinized and indented by a notch. On each side of the notch the margin forms a small lobe which carries a few coarse setae, those on the outer lobe being stouter than those on the inner lobe. The genital bulb is ovoid and bears a short thorn-like apophysis situated near the notch in the apical margin of the alveolus. The embolus is short and ends in a black point near the apophysis (fig. 27). The tibia is short and has the form of a shallow cup. It is provided with a single trichobothrium and is devoid of apophyses. Femur shorter than tarsus.

Abdomen. Oval, somewhat pointed posteriorly. Anterior part overhangs the carapace. Integument tough and coriaceous. It has a pitted appearance due to the presence of numerous small rounded sclerites carrying long hairs. Near the middle of the dorsal surface are two conspicuous muscle spots. At the sides the abdomen forms two longitudinal folds. The groove between the folds contains a row of sclerites. The ventral surface is covered anteriorly by an epigastric scute, which extends forward and surrounds the base of the petiolus. On each side the scute incorporates the elongated pulmonary plate. Behind the posterior lateral angles of the epigastric scute and extending backwards towards the spinnerets is a longitudinal row of four small sclerites on each side. In a median position between the epigastric scute and spinnerets are two pairs of small sclerites (fig. 28). The spinnerets and anal tubercle are surrounded by a chitinous ring, on the ventral side of which is the median tracheal spiracle. No colulus is present.







Atkinsonia nana Cambridge. Fig. 26: Chelicera of male. Fig. 27: Male palp. Fig. 28: Scutes on ventral surface of abdomen of male. Fig. 29: Epigynum of female in surface view.

FEMALE

	mm.
Total length	1·6240
Length of carapace	0·5800
Width of carapace	0·5500
Length of abdomen	1·2760
Width of abdomen	0·9860

Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
1	0·4521	0·1918	0·2740	0·2329	0·2877	1·4385
2	0·4247	0·2055	0·2740	0·2329	0·3288	1·4659
3	0·4110	0·2192	0·2740	0·2329	0·3836	1·5207
4	0·5069	0·2603	0·3699	0·2740	0·4110	1·8221
Palp	0·1370	0·0822	0·0959	—	0·1781	0·4932

The female closely resembles the male and only the following structures need be described.

Palpi. Tarsal segment longer than femur. Patella and tibia very short. Tarsus clothed with barbed hairs. Tarsal claw wide, spatulate and concave underneath. It has seven teeth on its front margin and presents the appearance of a small rake. It resembles the claw of *Hadrotarsus ornatus.*

Epigynum. Occupies a large portion of the epigastric scute. In surface view it has the form shown in fig. 29.

Locality. Mangarei, New Zealand. Mr. C. L. Wilton collected the female on 28th July, 1944, and the males on 24th September, 1944.

Atkinsonia petricola sp. nov.

MALE

	mm.
Total length	1·740
Length of carapace	0·754
Width of carapace	0·638
Length of abdomen	1·218
Width of abdomen	1·160

Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
1	0·5206	0·2055	0·3288	0·2740	0·3014	1·6303
2	0·4932	0·2055	0·3151	0·2466	0·2877	1·5481
3	0·4247	0·2055	0·2877	0·2192	0·3288	1·4659
4	0·5343	0·2329	0·3973	0·2877	0·3836	1·8358
Palp	0·2329	0·0959	0·1096	—	0·4795	0·9179

Colour (in alcohol). Carapace reddish brown with dark margin. Legs reddish brown above becoming darker underneath. Palpi chelicerae, maxillae, labium and sternum reddish brown. Dorsal surface of abdomen yellow marked with a pattern of irregular transverse black bars and round reddish spots (fig. 30). Sides yellow with black markings. Ventral surface reddish brown.

Carapace. Strongly convex, rounded at the sides and narrowed in front. Cephalic part high and projecting forward over the clypeus (fig. 31). Thoracic groove V-shaped. Radial grooves indistinct. Dorsal surface of head region clothed with light coloured hairs, which point forward. Clypeus and thoracic region devoid of hairs.

Eyes. Eight, arranged in two rows, which occupy the full width of the head region. Viewed from above the front row is strongly recurved and the posterior row almost straight. Ratio of eyes AME : ALE : PME : PLE = 5 : 7 : 7 : 7. The AME dark, the other eyes pearly white. AME separated from each other by once their diameter and from ALE by 3/5 of their diameter. Lateral eyes contiguous and projecting slightly at the sides. PME oval and separated from each other by 2/7 of their long diameter and from PLE by once their long diameter. Median ocular area wider in front than behind in ratio 14 : 13 and longer than its anterior width in ratio 17 : 14.

Chelicerae. Small and conical. Teeth and scopula absent. Fang long slender and curved, its length being greater than that of the paturon. In a position of rest the left and right fangs cross each other (fig. 32).

Maxillae. Triangular, converging in front of labium, furnished with a well developed serrula on the front margin and a scopula near the inner apical angle.

Labium. Triangular, rounded at the base and truncate at the apex. Wider than long in ratio 12 : 10. Clothed with a few hairs.

Sternum. Shield-shape, as wide as long, convex, truncate between the fourth coxae, which are widely separated. Margin rebordered and forming pointed projections between the bases of the coxae. Surface slightly pitted and clothed with fine hairs.

Legs. 4.1.2.3. Lightly clothed with fine hairs, those on the tarsi and metatarsi being barbed. Spines are absent. A basal and apical bristle on the dorsal side of each patella and 1 — 1 bristles on the dorsal side of each tibia. Four trichobothria

on the first three tibiae and five on the fourth. A single trichobothrium on each metatarsus near the middle. Tarsi longer than metatarsi. Three tarsal claws and setae modified as accessory claws are present. The upper claws are similar and have four teeth on the promargin and one on the retromargin. The lower claw is bent at a right angle and has one small tooth. The comb on the fourth tarsi is formed by a longitudinal row of six barbed setae. A small drum is present on the dorsal side of the tarsi near the base.

Palpi. The apex of the tarsus is narrow and conical. It ends in a hard black point (fig. 33). The alveolus is oval in shape. The middle of its apical margin is thickly chitinised and notched. On each side of the notch the margin is fringed with about six strong setae, which extend inwards across the bulb. Near the centre of the bulb is a short black thorn-like apophysis. The embolus is short and ends at one side of the apophysis. The tibia and patella are short and without apophyses. There is a single trichobothrium on the tibia.

Abdomen. Partly overlaps the carapace. The length is slightly more than the width. The integument is tough and leathery, having a punctate appearance due to the presence of numerous small rounded sclerites. The dorsal surface is almost flat, slightly procurved in front, rounded and somewhat undulating at the sides, clothed with short hairs and sloping posteriorly to a narrow point at the spinnerets. It is marked by a number of larger round reddish-brown sclerites arranged as shown in fig. 30. The sides of the abdomen have three longitudinal folds, which are continuous above the spinnerets. In the grooves between the folds are a number of sclerites (fig. 31). The base of the petiolus is surrounded by a chitinous ring, behind which is an epigastric scute, which incorporates on each side a large oval pulmonary plate. The anal tubercle and spinnerets are surrounded by a wide chitinous ring. On the ventral surface of the ring is the median tracheal spiracle. There are six spinnerets, the anterior pair being the largest. No colulus is present.

FEMALE

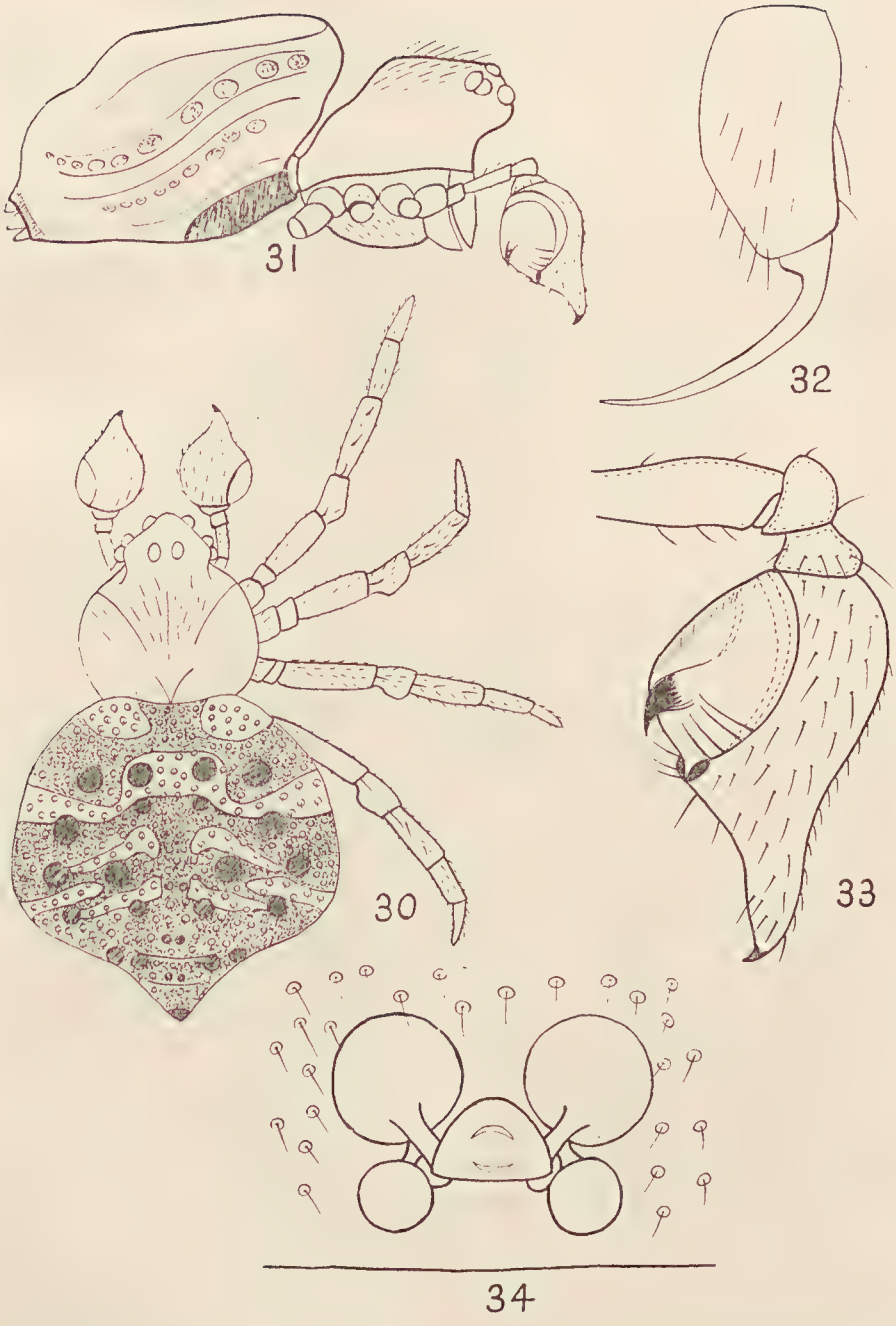
	mm.
Total length	1·740
Length of carapace	0·754
Width of carapace	0·580
Length of abdomen	1·334
Width of abdomen	1·334

Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
1	0·5069	0·2055	0·3014	0·2603	0·2877	1·5618
2	0·4658	0·2055	0·2877	0·2466	0·3151	1·5207
3	0·4247	0·2055	2·2877	0·2329	0·3425	1·4933
4	0·5480	0·2329	0·3973	0·2877	0·3836	1·8495
Palpi	0·1370	0·0822	0·0822	—	0·1644	0·4658

The female resembles the male in size, general appearance and colouration. However, the dark areas on the abdomen are usually smaller and may consist of a single irregular patch of black passing transversely across the middle of the dorsal surface.

Palpi. Tarsus longer than femur. Tibia and patella very short. A single trichobothrium on tibia. Tarsus lightly clothed with barbed hairs. Tarsal claw broad, rake-like and provided with nine teeth.

Epigynum. In surface view the epigynum appears as a small aperture with a rounded anterior lip. The aperture is situated on the epigastric scute in a median position slightly in front of the epigastric furrow. In transparent preparations two pairs of rounded spermathecae are visible, the anterior pair being larger than the posterior pair (fig. 34).



Atkinsonia petricola sp. nov. Fig. 30: Dorsal view of male. Fig. 31: Lateral view of male. Fig. 32: Chelicera of male. Fig. 33: Male palp. Fig. 34: Epigynum of female.

Locality. The type specimens, male and female, were collected together with a number of other adult and immature forms on the under surface of stones at Fern Tree, Mt. Wellington, Tasmania, 4th May, 1950.

My thanks are due to Mr. C. L. Wilton for specimens of New Zealand spiders and to Dr. Hamid Khan Bhatti of the Panjab University for literature not available in Australia.

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Pap. & Proc. Roy. Soc. Tasmania, 1950 (15th December, 1951)

The Aboriginal Rock Carvings at Mt. Cameron West, Tasmania, Photographs and Notes on the Excavations

By

L. E. Luckman

WITH 8 PLATES AND 1 TEXT FIGURE

Summary

This paper records the excavation of further aboriginal rock carvings at Mt. Cameron West, Tasmania and gives photographs of the most interesting groups.

Introduction

So far as is known at present, there are only three localities where rock carvings attributable to Tasmanian aborigines have been recorded. These are at Devonport (Meston and Scott, 1932), at Mt. Cameron West (Meston, 1933, 1934) and Trial Harbour (Jones, 1938).

The Devonport carvings are on dolerite, those at Trial Harbour on granite and those at Mt. Cameron West on calcareous sandstone. This last area contains the most numerous and certainly the most impressive examples of this type of native art yet discovered in the State. This article gives a key to their location and the photographs constitute a record of this important material, much of which may be lost by erosion. Meston (1932) and Crowther (1949) both referred to the rapid rate with which the carvings were deteriorating and in January 1949 it was obvious that the one illustrated in Plate IV of Meston's paper (1933) was in an advanced state of erosion. By February 1950 the carvings had broken in three pieces, one of which had disappeared. With the permission of the V.D.L. Company the remaining pieces have been removed to the Queen Victoria Museum, Launceston. Before the carving was moved a plane table survey of its position was made by Mr. W. D. Jackson.

The carvings are located about one chain above the High Water Mark approximately two miles north of Mt. Cameron West, Latitude 40° 50′ S, 144° 42·5′ E and are in two defined areas, a small one containing three carvings and a larger one of at least 50 carvings about seven chains further north (Text fig.).

Of the carvings in the smaller area, one, that removed to Launceston, has three parallel rows of indentations, a feature not found in any other carvings in either area. Of the two other carvings one is of a human face, having a circle for outline, two large indentations representing eyes, a verticle line for the nose and a horizontal line for the mouth. Across the top of the circle is the outline of a hat which bears a resemblance to the type worn by sailors of the late 18th century. It is possible that the original carving consisted of a circle and two indentations only as the outline of the hat is slightly shallower while the nose and mouth lines, being shallower still and showing little signs of erosion, could have been added at a much more recent date. A somewhat similar design of two indentations in a circle may be seen on the removed carving.

In the larger area before excavation commenced the only carvings visible were those on 12 blocks of talus and those on the overhanging cliff above. Subsequent removal of shrubs, creepers and a considerable depth of sand uncovered 14 more blocks.

It seems probable that the cliff face had been undermined by the sea and large blocks had fallen and piled at the foot of the cliff. These blocks were carved where they fell, all available surfaces being used. Many of these were later covered by sand blown in from the seaward side.

Thirty-six of the carvings are on the natural bed surface and the others on end grain. They vary considerably in shape and size from one square foot to 35 square feet but each design, whether simple or complex, has been executed with a good sense of proportion and balance. The stone was easy to carve owing to its low crushing strength; in its present state it is possible in many cases to rub a groove with finger pressure only, particularly where the surface has been covered for some time with sand. Methods used by the aborigines in carving could have been hammering, gouging, rubbing or a combination of these. On certain of the carvings final rubbing is the only way in which they could have obtained the good sharp edge which still holds even to-day.

During excavations four small, flat stones oval in shape and averaging two inches long by one and a quarter inches wide were found, one at the base of the carving No. 18 and three under 19a. It is possible that these stones were used for rubbing the designs above since they fitted the grooves, although they showed no apparent signs of wear.

General Description of the Carvings

For purposes of reference each rock bearing a design has been numbered, the various rocks being subdivided and referred to as A, B, . . . G. The numbering of the carvings and their position in relation to the overhanging cliff are illustrated in the text figure.

Text Fig.—Key showing position of carvings in relation to the cliff.

Where the covering sand was damp, particularly on horizontal surface, the carved rock had merged with the sand itself, while those which had become covered with vegetation, flaked off through the penetration into the sandstone of countless fine rootlets. Hence, excavation had to be done very carefully, the bulk of the sand being hoed away to within some inches of the rock surface, the rest removed by hand and when dry the carvings lightly brushed.

Prior to the excavation No. 3 was partly covered with sand and vegetation, Nos. 10 and 11 completely covered, No. 13 nearly completely covered, Nos. 14, 15 and 16 completely covered, No. 16a partly covered, 16b completely covered, Nos. 18-23 almost or completely buried.

A bank of drifted sand hid No. 19 and part of 22 and completely filled the gap between them to within a few inches of the bottom of the top block No. 20. After 14 inches of sand between 19 and 21 had been removed a three-inch layer of small mussel shells was found together with a quantity of charcoal in the innermost corner against 21; beneath this was a two-inch layer of sand then another layer of midden material including mussel, turbo and haliotis shells and charcoal for four inches; then sand again for 14 inches followed by another layer of mussel, turbo, haliotis shells and charcoal for nine inches. About halfway through this layer was found a waterworn rock; bearing traces of red ochre on one side which may have been a grinding stone of pestle; also in this layer were the three small stones mentioned earlier.

About another three inches of sand brought the excavation to the bases of 19 and 23. For at least three different periods, therefore, the shelter formed by 19, 20 and 21 was used for a cooking fire and the carvings were in existence when the aborigines were still living in the district.

After excavation the carvings were photographed untouched and then outlined with chalk or charcoal and photographed again.

For reasons of economy all the photographs cannot be reproduced here but the more interesting carvings are represented in Plates I-VIII. A fuller range of photographs has been deposited in the Society's Archives.

Acknowledgments

The author wishes to thank the V.D.L. Company for permission to carry out the excavations and to Mrs. L. E. Luckman, Mr. and Mrs. W. D. Jackson and Mr. F. Ellis for invaluable assistance in this work.

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Fig. 1.—Carvings 18-23 partially excavated × $\frac{1}{10}$

Fig. 2.—Detail of 18 (left) and No. 20 top right × $\frac{1}{32}$

FIG. 3.—Carving No. 19 outlined with charcoal to show detail $\frac{1}{10}$

FIG. 4.—General view showing 20A (foreground and 16B and 17B (background) $\times \frac{1}{10}$

Fig. 5.—Detail of No. 23.

Fig. 6.—Detail of No. 22A × $\frac{1}{12}$

FIG. 7.—Detail of No. 21 × $\frac{1}{4}$

FIG. 8.—Detail of No. 3. Note severe erosion on the right hand side where a layer of rock has faced off. No. 2 is just visible as a circle under the overhanging rock above × $\frac{1}{4}$

Fig. 9.—General view of No. 6-11 × $\frac{1}{4}$

Fig. 10.—Detail of No. 6 × $\frac{1}{10}$

FIG. 11.—Detail of No. 7 × $\frac{1}{10}$

FIG. 12.—Nos. 10 and 11 × $\frac{1}{16}$

Fig. 13.—No. 13 general view × $\frac{13}{40}$

Fig. 14.—No. 14 × $\frac{1}{2}$

FIG. 15.—Detail of 16B × 1.

FIG. 16.—General view showing No. 24. Under the ledges of the overhanging cliff in the background are 25 and 25A, the former being above the reach of the average man.

Pap. & Proc. Roy. Soc. Tasmania, 1950 (15th December, 1951)

The Intertidal Ecology of Pipe Clay Lagoon

By

Eric R. Guiler

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(Read 7th November, 1950)

WITH 2 PLATES AND 8 TEXT FIGURES

Summary

This paper is the second dealing with various aspects of the intertidal ecology of Tasmania. Pipe Clay Lagoon is a sheltered area of water which is populated by a fauna characteristic of such places. The main deductions of the effect of climate on the intertidal organisms (see Guiler, 1950) are applied to the lagoon. The detailed zonation of the lagoon is described. There exist a series of belts on the shore from an *Arthrocnemon* scrub at the Supralittoral to *Pyura* on the floor of the lagoon. In many cases the dominant species is difficult to separate from other species and population counts have to be made. For this and other reasons enumerated in the text it has been found that for most practical purposes, other than detailed surveys, it is possible to consider the zoning of the shore as being the Upper Shore with *Arthrocnemon*, the Supra *Zostera*, the *Zostera*, the Infra *Zostera* and the Lagoon Bottom.

A detailed description of a transect is given and comparisons made with other places on the shore of the lagoon. The prevailing wind has an interesting effect on the distribution of *Zostera* beds, the plant being found much further up the shore at the southern end of the lagoon, the prevailing winds being in the North quarter.

The entrance to the lagoon is narrow and there is a considerable tidal current in this strip of water. In spite of this there is no luxuriance of forms, the probable reason for this poverty being the presence of a very considerable amount of silt.

A feature of the shore in certain parts of the lagoon is the presence of the soldier crab, *Mictyris platycheles* Milne Edwards. This crab lives in very large numbers in the lagoon but it was found that it is confined to a certain type of substratum. The muddy substratum is characterised by the crab *Paragrapsus gaimardii* (Milne Edwards) while *Mictyris* lives in more sandy mud. It is possible to classify the lagoon shore into two types of substratum, a *Mictyris* sand and a *Paragrapsus* mud. Some reasonably accurate faunal predictions can be made from the substratum encountered.

An attempt is made to correlate the zoning seen in a lagoon with that on other types of coast. A food chain for organisms living in the lagoon is given.

Introduction

This is the second of a series of papers dealing with various aspects of the intertidal ecology of Tasmania. The first paper described the features of a semi-exposed coast at Blackman's Bay (Guiler, 1950) and the present paper deals with the intertidal areas of Pipe Clay Lagoon.

Pipe Clay Lagoon was chosen as the first place to study the ecology of enclosed areas of water and this paper embodies the results of numerous visits to the lagoon.

The list of species found in the lagoon is not complete. All of the large forms found dwelling on the surface of the lagoon are listed but subsurface species have not been fully investigated. Some of the burrowing animals are mentioned but many others have not been identified due to lack of studies on several groups of Tasmanian animals.

Pipe Clay Lagoon is a small area of sea water which is almost entirely surrounded by land. The lagoon opens by a narrow strip of water at its north-eastern side into the western side of Frederick Henry Bay (Text figure 1). The water in the lagoon is very shallow and large areas of shore are exposed at low tide (see Plate I).

FIG. 1.—General map of part of southern Tasmania showing the location of Pipe Clay Lagoon. Scale approx. 4 miles to inch.

Transects were examined at the northern and southern ends of the lagoon and examinations of the shore were carried out at all other places of the lagoon. The narrow entrance to the lagoon received particular attention. Transects were not examined at this place but the shore was intensely searched in a direction parallel, rather than transverse, to the shoreline.

The terminology used is the same as that employed in the previous papers of this series and follows that of Stephenson & Stephenson (1949). The tidal terminology is that of Chapman (1938).

Pipe Clay Lagoon lies approximately in 42° 57′ S., 147° 34′ E. It forms a feature of the small peninsula lying between the estuary of the Derwent on the West and Frederick Henry Bay on the East. The lagoon is over two miles in length and three-quarters of a mile in width. The four main features of the lagoon to be considered are the north, west and south bays and the narrow channel connecting the lagoon with the open sea.

The shore of the lagoon is level, with the low land immediately above it often marshy. On the southern side of the entrance channel there are low cliffs. The nature of the bottom of the lagoon will receive attention in the sections on substratum.

Physical Environment

(1) *Tides*: The tides have the same behaviour as those described for Hobart (Guiler, 1950). There is, however, a considerable difference in time between the various phases of the tides in the lagoon and those in the Derwent Estuary. This interval may be as much as three hours.

(2) *Wind:* The wind has a marked effect on tidal levels in the lagoon, and may act in two ways. Firstly, it may blow water in or out of the lagoon causing very high tides or very low tides, with consequent variation in exposures. Secondly, it may have a purely local effect on one area of the shore. A slight breeze has been noticed to cause water in the lagoon to advance for three feet or more over the exposed lagoon floor. The effect of this on a larger scale will be seen in relation to the distribution of the *Zostera* beds.

(3) *Climatic Factors:* The climate of this area resembles that of Hobart with the exception of rainfall, which is less on the eastern side of the Derwent than on the western side. The rainfall at Hobart and Sandford over 68 and 47 years respectively, as given in the Weather Bureau records (1936), show that the rainfall at Sandford is about two inches less that at Hobart.

The lower salinities experienced during rainfall are counteracted by the amounts of salt water retained on the lagoon shore.

In a previous paper (Guiler, 1950) it was noted that December, January and July are critical months for intertidal organisms at Blackman's Bay and there is no reason for modifying this conclusion for Pipe Clay Lagoon.

(4) *Sea Temperature:* The only observations made on the temperature of the sea are a few readings taken to show the effect of hot weather on the incoming tide. Ordinary sea temperature being about 19° C., the temperature of water left in hollows in the sand reached 27·5° C. and the temperature at one inch depth in the sand was 25° C. The temperature of the incoming tide varied considerably with the local currents. In some places a temperature of 23° C. was recorded at the water's edge. This is caused by a cooling of the water retained on the foreshore rather than by a heating of tidal waters. In general, however, tidal waters were heated to a more or less extent for some 50 feet from the advancing edge of the water.

(5) *Currents:* Strong tidal currents are set up in the channel connecting the lagoon to the open sea. This channel is deep and is rocky on the southern side. In the lagoon there are certain well defined channels by which water enters or leaves the area. (Plate I.) Since 1948 these channels have varied slightly in position.

(6) *Substratum:* Most of the lagoon is covered by a sandy mud, but the southern bay is more shaley than the other two bays. Throughout the bays the surface layer of sandy mud or muddy sand is only about two inches deep. Below this is a bed of black organic mud containing some shell fragments and below this is a stratum of shells.

In the southern bay of the lagoon there is some difference in the substratum in the higher levels of the shore, white sand being found above the black organic mud. At G (Text fig. 2), the substratum is composed of a surface, one-quarter of

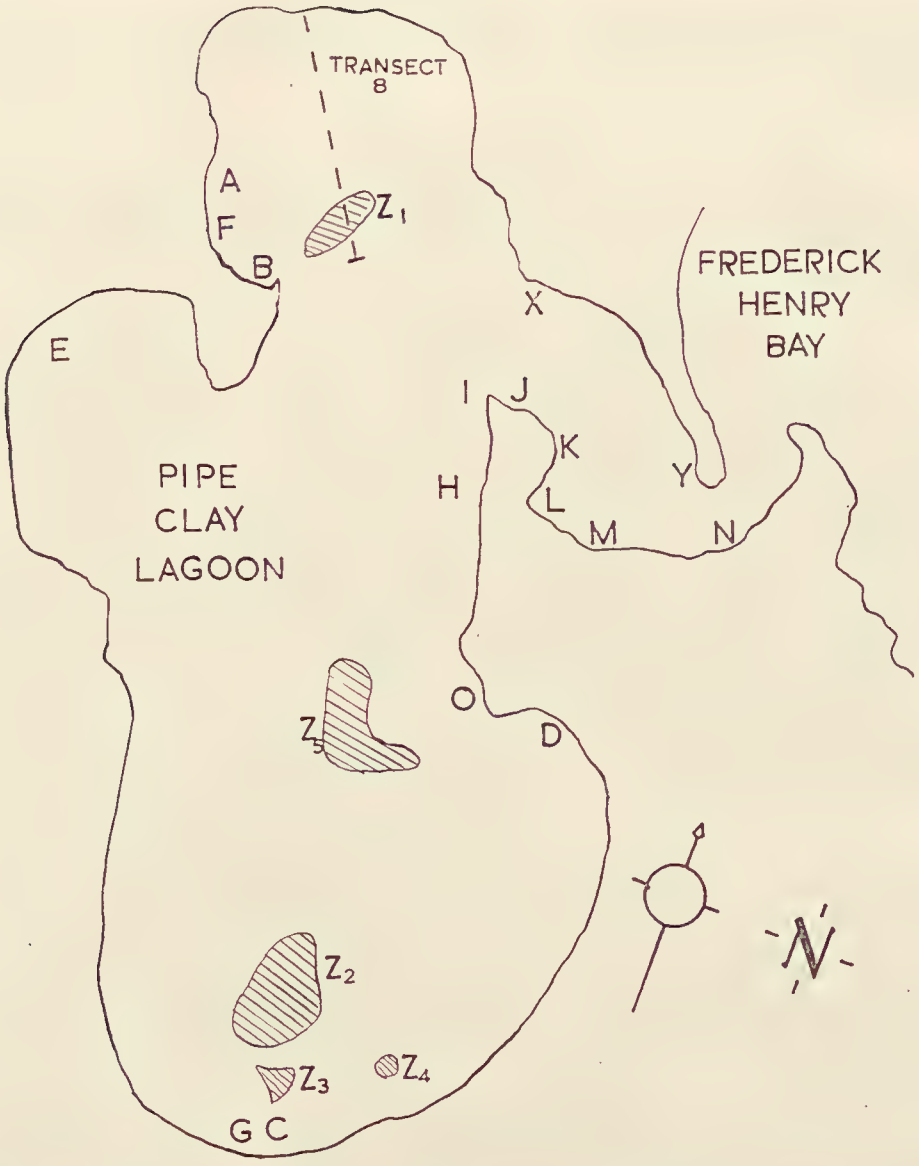

Fig. 2.—Detailed map of Pipe Clay Lagoon. Scale approximately 1 mile to 4 inches.

an inch thick, of golden sand with a thin belt of organic mud below it. This alters into one and a half inches of white sand with another layer of mud. Below this is the shell bed which extends over all the lagoon at a depth of about three inches.

There are a few small rocky outcrops in the lagoon. These are of dolerite on the western side of the lagoon and mudstone on the east. The outcrops, except where they form fringing cliffs, do not project above the lagoon floor. They are recognized by the presence of numerous stones on the shore of the lagoon. The rock is usually covered by a thin film of muddy sand.

There is a very sharp difference in the topography of the northern and southern sides of the entrance to the lagoon. The north shore has a substratum of firm, fine hard sand which gradually changes into a muddy sand on mixing with the more muddy lagoon deposits. This muddy sand has few shell fragments. At X (Text fig. 2) the muddy sand changes into a sandy mud with numerous shell fragments. In the other direction the fine sand continues along the open sea shore known as Cremorne Beach.

On the southern side of the entrance the shore is rocky with a stony foreshore and low cliffs of mudstone. At the lagoon end of the rocky headland (at Y) the shore immediately changes into sandy mud. The point at the southern seaward end of the entrance to the lagoon is of dolerite and this rock continues along the ocean coast.

(7) *Salinity:* The lagoon has a higher salinity than the open sea. Full and regular observations have not been made but two analyses made during spring weather showed salinities of 36·5 grs./mille and 37·1 grs./mille. The salinities were determined by the titration as outlined by Harvey (1945, p. 20). The pH, determined by an electrometer, was 8·1.

Zonation

The ecological features of the lagoon will be considered in two sections, A and B. Section A will include the features of the lagoon proper and Section B will describe the features of the entrance channel. For the purposes of this work the entrance channel will be assumed to extend from the entrance to the line X-Y (Text. fig. 2).

Section A

Transect 8

Station	Pipe Clay Lagoon.
Date	December, 1948, and various subsequent dates.
Type	Lagoon.
Maximum Wave Exposure	*s* (1-6), 0, *b* 1.
Description	The transect lies in the northern bay of the lagoon and runs from just below a large obvious tree on the roadside, past the line of telegraph poles to beyond the *Zostera* bed.
Geology	Sandy mud with a few small outcrops of dolerite.
Tidal data	As for Hobart.
Physical Environment	As above.
Zonation	There undoubtedly exists a zonation of the forms found in the intertidal regions of the lagoon; but this zoning is difficult to identify. Certain species are dominant and may be used as indicators but in many cases their limits are so extended outside their dominant range that their value as indicators is greatly reduced (see *Bembicium* on Text fig. 3). Further, some of the dominant species are burrowing in habit and others are very small. Also, some species which are both obvious and numerous, never achieve dominance, e.g., *Paranassa pauperata* (Lam.). Therefore, while listing a zonation below, it must be borne in mind that this zoning may not be very obvious and considerable examination of the shore must be undertaken before it is possible to decide the dominant form in the zone being examined. For most practical purposes, other than detailed surveys, it is possible to divide the shore into five zones. These are the Upper Shore; the Supra *Zostera*; the *Zostera*; the Infra *Zostera* and the Lagoon Bottom. The detailed zonation is *Arthrocnemon arbusculum* (R. Br.) Moq., *Salinator solida* von Martens, *Bembicium melanostoma* (Gmelin), *Bittium lawleyanum* Crosse, *Anapella cycladea* (Lam.), *Zostera nana* Roth., *Marcia corrugata* (Lam.), *Austrocochlea obtusa* (Dillwyn),

The features of each of these zones will now be described.

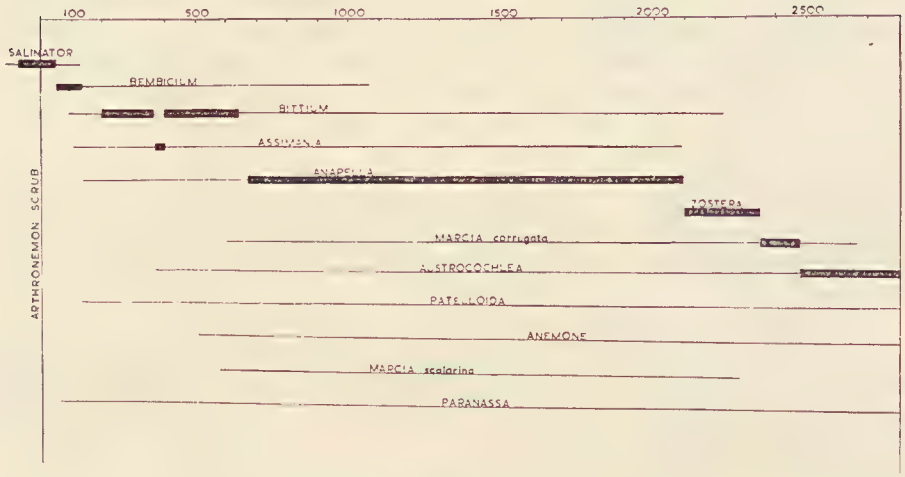

FIG. 3.—Detailed zonation at Pipe Clay Lagoon. Distances in hundreds of feet from the *Arthrocnemon* scrub.

The Upper Shore

The Upper Shore is populated by a growth of *Arthrocnemon arbusculum.* This plant forms a scrub-like growth up to two feet six inches in height. *Salicornia australis* Sol. which may be classed as a sub-dominant, is the chief constituent of a dense mat of procumbent plants extending from above 'high high' water mark to the lower limit of the Upper Shore. *Salicornia* extends from the driest parts of the formation to the wettest. On the seaward side in all but the wettest parts of the marsh *Samolus repens* Pers. is found with the *Salicornia, Arthrocnemon* is frequent, *Suaeda australis* (R. Br.) Moq. is common and *Wilsonia backhousii* Hook. is found in the drier parts.

Towards the landward side, as the soil becomes richer in organic matter and drier, *Arthrocnemon* and *Samolus* are still frequent, *Suaeda* remains common and *Wilsonia* becomes more frequent at the expense of *Salicornia.* Grass occurs occasionally. Finally, Cyperaceous dry-land plants appear and *Arthrocnemon* disappears.

There are very few intertidal species found in this part of the shore. In the lower and wetter parts of the formation the gastropod *Salinator solida* is very common. The species is largely confined to muddy patches and drainage channels in the marsh. In these places as many as 30 individuals per square foot have been found. A few specimens of *Bembicium melanostoma* were found and one *Paragrapsus gaimardii* (M-Ed.) was captured at the extreme seaward edge of the marsh.

Numerous dead mollusc shells and crab carapaces are to be seen hanging from the *Arthrocnemon* shrubs and lying on the *Salicornia* mat. These probably are deposited during abnormally high tides in easterly weather.

The Supra Zostera Zone

Most of the area of the transect falls into this zone. The *Zostera* forms a small bed about 700 yards from the *Arthrocnemon* scrub. The zone, as mentioned above, can be divided into a series of belts. These can be distinguished only by a close examination of the fauna.

The zone may be considered in terms of the various indicator and other species and their distribution. Text figure 3 shows the ranges of the most common species on the shore.

Salinator solida von Martens

This gastropod is found both in the Upper Shore and in the first 120 feet of the Supra *Zostera*. Throughout this range it is very common and is dominant for the first 50 feet of the lagoon shore proper.

The only other species found in the belt dominated by this species are a few *Bembicium melanostoma* and *B. nanum* (Lam.) and some small crabs *Paragrapsus gaimardii*.

Bembicium melanostoma (Gmelin)

Throughout this work this species is that identified by May (1923).

This species is present for 1060 feet of the transect. It first appears just below the *Arthrocnemon* scrub and follows the *Salinator* belt, being dominant for 95 feet below the latter belt but the species still occurs further down the shore and does not become rare until the last 400 feet of its range. Other species found in the upper part of the belt dominated by *Bembicium melanostoma* are the crab *Paragrapsus gaimardii*, *Salinator solida* and one individual of *Austrocochlea obtusa* (Dillwyn).

In the lower part of the belt are *Bittium lawleyanum* Crosse, *Assimania brazieri* (Ten.-Woods), *Mactra rufescens* Lam. (one individual only), and one individual of *Anapella cycladea*. *Assimania* becomes very common in the last 40 feet of the *Bembicium* belt. Here also the limpet *Patelloida subundulata* (Angas) is found adhering to solid objects, usually shells. May (1923) considers that this species may be a variant of *P. conoidea* Quoy & Gaim. The latter species is found on wave exposed coasts and also occurs in small numbers in the entrance to the lagoon.

The density of the population of *Bembicium melanostoma* is very varied. Between 20 and 40 feet from the *Arthrocnemon* scrub four random counts showed that there were 2, 2, 1 and 0 individuals per square foot respectively. Local concentrations of as many as 8 per square foot were recorded. At 70 feet from the top of this belt several random counts showed that there were four individuals per square foot.

The gastropod *Paranassa pauperata* (Lam.) was first noted at low water in the last 20 feet of the *Bembicium* belt. At 'high high' water this species was observed in all but the top 20 feet of this belt. Johnston and Mawson (1946) note that *Paracanassa pauperata* buries itself in the sand and readily comes to the surface when food is available. It seems probable that the Tasmanian carnivores bury themselves shortly after the tide has exposed them and reappear when the tide has covered the sand. They will appear if food is left on the surface of the shore and trampling of the sand also brings them to the surface.

Digging into the substratum as far as the shelly bed failed to reveal any burrowing molluscs. Worms (? *Leptonereis* sp.) were encountered but were not common.

Immediately following the *Bembicium* belt is a mixed strip containing *Bittium lawleyanum* and *Assimania brazieri* of which the former ultimately becomes dominant.

Bittium lawleyanum Crosse

This species has already appeared in the *Bembicium* belt and becomes dominant at a distance of 180 feet from the *Arthrocnemon* scrub. It remains dominant, with one small break, for 440 feet. Eighty feet after the commencement of this belt a small strip 20 feet wide is dominated by *Assimania brazieri*. *Bittium* is found as far down as the Infra *Zostera* zone at a distance of 2400 feet from the *Arthrocnemon* scrub.

The species also found in this belt can be divided into two ecological groups, those from the belts above and those from the belts below that dominated by *Bittium*. The former group contains such animals as *Assimania brazieri, Patelloida subundulata, Austrocochlea obtusa, Paranassa pauperata* and *Paragrapsus gaimardii*. Species found only below the *Bittium* belt but which appear in that belt are *Anapella cycladea, Polinices conicus* (Lam.), *Marcia scalarina* (Lam.), *Marcia corrugata* and *Cominella lineolata* (Lam.). *Anapella cycladea* was recorded as being found in the *Bembicium* belt but as only one specimen was found the species is noted here as occurring below the *Bittium* belt.

An anemone, *Anthopleura aureo-radiata* (Stuck.), appears 460 feet from the *Arthrocnemon* scrub. Only the tentacles and oral surface of the anemone appear above the sand. The aboral surface adheres to the shells of burrowing lamellibranchs. In the *Bittium* belt the shore is fairly level and there is usually sufficient water retained between ridges in the sand for the anemones to remain partly expanded throughout the intertidal period.

At a distance of 420 feet from the *Arthrocnemon* scrub an interesting algal growth appears. The algae concerned are Cyanophyceae, mostly *Oscillatoria* sp. These algae are filamentous and form small mats which become closely congested with sand grains and mud. The mats are ovoid in shape and measure up to two inches across the long axis and about a quarter of an inch in thickness. They lie scattered over the shore, and are scarce at first but further down the shore they become more numerous. Further notes on the mats are given below. The small gastropod *Assimania brazieri* was noted as not occurring on the mats in this belt but further down the shore in the *Anapella* belt the species occurs on the algae.

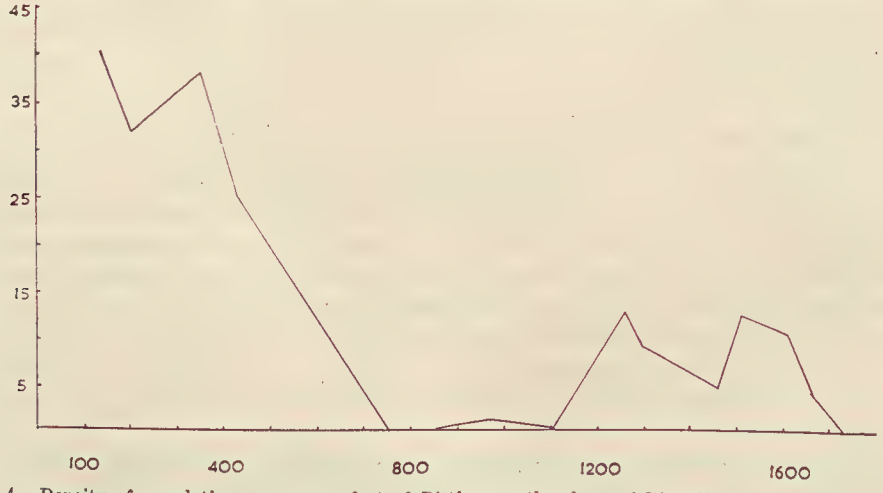

FIG. 4.—Density of population per square foot of *Bittium* on the shore of Pipe Clay Lagoon. Distances in hundreds of feet from the *Arthrocnemon* scrub.

At the lower end of the *Bittium* belt one of the few barnacles encountered on the transect was found living on the shell of a *Bembicium melanostoma*. The barnacle was an *Elminius modestus* Darwin.

The density of the population of *Bittium* is very variable throughout the zone (Text fig. 4). At the beginning of the dominance of this species there were in two counts 35 and 45 individuals per square foot with 30 and 30 individuals of *Assimania brazieri* respectively. At the end of the dominance of *Bittium* there were 25 individuals per square foot. The species, although present over most of the shore, falls off in numbers beyond its area of dominance and counts taken further down the shore showed a very variable population.

Anapella cycladea (Lam.)

This species first appears at the end of the *Bembicium* belt and becomes dominant 680 feet from the *Arthrocnemon* scrub. It remains the dominant species as far as the *Zostera* bed a further 1420 feet away. The lamellibranch sometimes occurs at the surface of the sand but usually is found burrowing in the thin sandy belt above the black organic mud. All counts of this and other burrowing species were made in a one foot square to the depth of the shell bed.

Species noted for the first time in this belt are *Friginatica beddomei* (Johnston), a burrowing worm which leaves obvious casts (? Fam. Maldanidae) and *Salinator fragilis* (Lam.). The worm casts become more plentiful in the lower parts of the belt.

As noted above, *Assimania brazieri* was found living on the algal mats in this belt. In the lower parts of the belt, up to 400 feet before the *Zostera*, this species was noted as being found in puddles of water and not on the, by then, scarce algal mats.

Other previously noted species found in this belt are *Marcia corrugata, Marcia scalarina, Bittium lawleyanum, Paragrapsus gaimardii, Mactra rufescens, Paranassa pauperata, Cominella lineolata, Patelloida subundulata, Austrocochlea obtusa, Elminius modestus* and *Oscillatoria* sp.

A telegraph pole 80 feet from the beginning of this belt had a cluster of barnacles on its sun-sheltered side. The barnacles reached a height of nine inches above the sand (Plate II). The barnacles were mostly *Elminius modestus*.

A feature of this zone is the remarkable uniformity of the fauna inhabiting it. In a distance of 1420 feet only three species, listed above, are found which do not occur in previous belts. Of these species only the burrowing worm is common, the other two being represented by scattered individuals.

The density of the population of *Anapella* is summarized in Figure 5. The species is most numerous between 700 and 1000 feet after the beginning of the belt. The species density varies between 15 and 30 individuals per square foot over most of its range. The maximum density encountered was 32 per square foot.

The Zostera Zone

The belt dominated by *Zostera nana* follows sharply after the *Anapella* belt. The *Zostera*, forming a firmly aggregated mass, prevents the passage of the burrowing lamellibranchs.

The *Zostera* bed is raised about one or two inches above the general level of the surrounding lagoon shore. This has the effect at low tide of enclosing on the inshore side of the *Zostera* a pond of considerable area but very shallow depth. The presence of this water does not appear to alter the constitution of the fauna of the immersed portion.

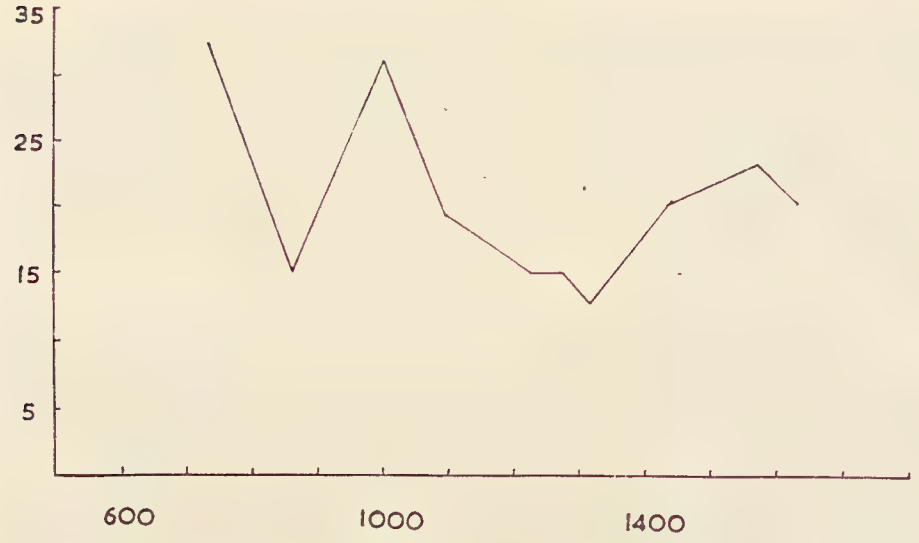

FIG. 5.—Density of population per square foot of *Anapella* on the shore of Pipe Clay Lagoon. Distances in hundreds of feet from the *Arthrocnemon* scrub.

The sea grass does not form a fully developed Zosteretum as the characteristic fauna of such a habitat is absent. Species are found which appear for the first time, namely *Brachyodontes rostratus* (Dunker), *Venerupsis diemenensis* Quoy & Gaim., *Lucinida assimilis* (Angas), *Pyrazus australis*, *Fasciolaria australasia* Perry, *Ostrea virescens* Angas, two species of Nemertines and small individuals of *Leander intermedius* Stimpson.

Of the above species only the Nemertines and *Pyrazus australis* are not found in other places in the lagoon. The shrimp is found in the pool behind the *Zostera* bed. This latter species is seasonal in its occurrence, being only found in the late summer.

Other species found in the *Zostera* bed are *Salinator fragilis*, *Patelloida subundulata*, *Bittium lawleyanum*, *Cominella lineolata*, *Marcia scalarina* and *M. corrugata*, *Paragrapsus gaimardii* and *Elminius modestus* attached to *Brachyodontes rostratus*.

It is evident from the extent of large 'peaty' deposits that the *Zostera* beds were, until recently, of greater area than at present. In particular, the beds must have extended further out into the lagoon and to the east of their present limits. The fauna living on these old beds is poor but does not contain any of the forms noted above as being confined to the *Zostera* beds. *Paragrapsus* makes large burrows in this 'peaty' material.

Marcia corrugata (Lam.)

This species becomes dominant immediately after the *Zostera* belt, i.e., on the old *Zostera* beds and the sandy mud further out. There are no species appearing for the first time in this belt.

Other species found are *Elminius modestus* and *Chthamalus antennatus*, *Patelloida subundulata*, *Paranassa pauperata*, *Cominella lineolata*, *Bittium lawleyanum*, *Austrocochlea obtusa*, *Venerupsis diemenensis* and *Brachyodontes rostratus*. There are no burrows of *Paragrapsus gaimardii* beyond the first 30 feet of this belt.

Austrocochlea obtusa (Dillwyn)

This gastropod is distributed throughout most of the shore. One individual was found in the *Bembicium* belt and a few in the *Anapella* belt. Searching did not reveal a large number of specimens and it is thought that these few individuals may have been accidentally distributed. In this connection it is worth noting that many shells of various species are found littering the shore of the lagoon, and care has to be exercised that shells identified are inhabited. Numerous shells were found but do not appear in these lists as they were not inhabited. Stephenson (1939) makes similar observations about the distribution of South African molluscs.

Austrocochlea obtusa suddenly appears in large numbers 2470 feet from the *Arthrocnemon* scrub. It becomes dominant almost immediately. The *Austrocochlea* belt is about 320 feet in width, extending as far as the Lagoon Bottom.

Other species found are *Ostrea virescens* (not plentiful), *Venerupsis diemenensis, Marcia corrugata.* The latter species is in large numbers and in places ranks as a co-dominant. *Anapella cycladea, Lucinida assimilis, Mytilus planulatus* Lam., *Brachyodontes rostratus, Patelloida subundulata, Paranassa pauperata* and *Cominella lineolata* are also found. Only one specimen of *Anapella cycladea* was recorded in the course of several visits and the presence of this species must be regarded as doubtful. *Paragrapsus gaimardii* is found living in the byssus threads and below the colonies of mussels. *Elminius modestus* and *Chthamalus antennatus* are found attached to mussels and isopods and amphipods are very numerous swimming in the water retained on the shore.

Notes on Other Species

(*a*) *Patelloida subundulata* (Angas)

This small limpet has a very considerable dessication toleration, being found in the *Bembicium* belt and extending as far down the shore as the lower tidal limits. During the summer the individuals in the *Bembicium* belt are exposed to the air and sun for most of the period of daylight. The dessication effect of the sun is supplemented by the possibly greater effect of the wind which is nearly always blowing across the lagoon.

The limpets living at the top of the shore are very easily removed from their substratum. The foot in many instances showed signs of drying and the animal was not in a very healthy state. At a distance of 260 feet from the *Arthrocnemon* scrub it was noticed that the limpets had a more firm grip on their substratum.

The limpets use any solid object as a substratum. Small pebbles, which are few in number, and shells, either living or dead, are used. If shells are used a preference seems to exist for those which are occupied by an animal. In the Upper Shore this is usually *Bembicium melanostoma.* In the lower shore regions many *Anapella,* living just below the surface, have one valve projecting above the sand with a *Patelloida* living on it. In the lower tidal areas there is not much preference shown for habitat except that *Paranassa pauperata* is never occupied by limpets. *Bittium lawleyanum* and *Assimania brazieri* are not used as a substratum due to their small size.

Paragrapsus gaimardii (Milne Edwards)

This crab is common throughout the whole of the area examined. The crabs spend the intertidal period in either permanent or temporary burrows in the sand. The larger crabs make large permanent burrows but the smaller individuals seem

to be content to bury themselves at any convenient place. When covered by the tide these crabs scuttle about on the bottom seeking food and, on alarm, they either bury themselves or assume a fighting pose.

There exists a very definite size distribution of this species on the shore. Small individuals are found at both the upper and lower tidal levels. The largest crabs, of up to 5·5 cm. in carapace width, are found immediately below the *Zostera* bed. Large crabs may be seen scuttling about the Lagoon Bottom in non-tidal waters. These crabs sometimes invade tidal waters in large numbers for sunbathing.

At low tide, usually on days with hot sun, these crabs are to be seen sunbathing at various places on the shore. The edge of the sea may be crowded with crabs from non-tidal waters. The crabs stand on the extreme tips of their claws with the body raised high off the ground.

Philyra laevis Bell

I have not mentioned this crab in the text above as there is some doubt as to its behaviour. At high water these crabs can be found at the highest levels reached by the tide, but digging at low tide produced only one specimen and it is concluded that it is a Lagoon Bottom dweller. It invades the tidal areas with the flow tide and retreats again on the ebb. It is most commonly found in the drainage channels which contain permanent water. In the channel to the east of this transect these crabs can usually be found buried with only their eyes and claws projecting from the sand. They can move fairly rapidly and cover considerable distances in search of food.

The species is both a predator and a carrion feeder. It will feed greedily on a *Paragrapsus* which has been trampled underfoot, using both chelae in what can only be described as an orgy of feeding.

Paranassa pauperata (Lam.)

As noted above, this species is found over nearly all of the area of the transect. Its role is that of the carnivorous predator and carrion feeder. At low water the species is inclined to bury itself in sand especially if it lives in the higher tidal levels. In those parts of the shore where water lies in hollows the species does not seek protection by burying. At high water or where there is more or less permanent water it roams across the sand seeking out lamellibranchs or dead crabs. These form its main food supply.

The hunting is conducted by a strong sense of smell. During a period with a moderate wind a lamellibranch *(Marcia scalarina)* was opened and placed on the sand. Within very few minutes the gastropods were approaching from all sides. Those upwind (and therefore on the weather side of the surface water drift) were attracted within a foot or so of the prey but from as much as four or five feet downwind animals were proceeding towards the food. The course pursued is zig-zag as if the animal were using an average intensity of smell as a course. When close to the prey the gastropod moves straight towards it. Within five minutes, five animals were feeding on the lamellibranch, four were coming downwind and five more were coming upwind to the food. In one and a half hours time the mollusc was devoured and the gastropods dispersed.

Spisula trigonella (Lam.)

This species occurs sporadically throughout most of the Supra *Zostera* zone. It is never plentiful and is found burrowing in the subsurface layers.

Assimania brazieri (Ten. Woods)

This small gastropod first appears on the shore in the lower *Bembicium* belt and extends as far as the *Zostera* bed. The species does not live on the *Zostera* nor on the shore below the sea grass. At about 700 feet from the *Arthrocnemon* scrub the species is frequently found in large numbers (as many as 10 individuals per square foot) on the algal mats described below. At lower levels where the algal mats are not so common the species occurs on the surface of the sand usually in places where it is covered by water. Figure 6 shows the density of the *Assimania* population at certain places on the shore. The species becomes locally dominant in small areas and numbers as many as 30 individuals per square foot. These small patches, with one exception, have not been included in the zonation outlined above as they are purely local in occurrence.

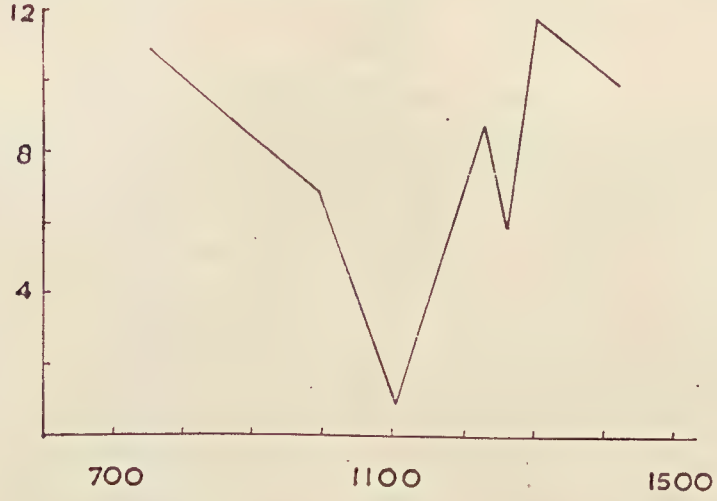

FIG. 6.—Density of population per square foot of *Assimania* on the shore of Pipe Clay Lagoon. Distances in hundreds of feet from the *Arthrocnemon* scrub.

Algal mats

At approximately 420 feet from the *Arthrocnemon* scrub small mats or pads of sand were noted on the shore (Plate II). These pads extended as far as 200 feet from the *Zostera* belt. At this place they were replaced by worm casts. The sandy mats and worm casts are not usually co-existant.

On examination these mats were found to consist of numerous strands of blue-green algae, a species of *Oscillatoria* forming the largest proportion of the algae. Mixed with the algae were sand grains.

The pads ranged in size from about half an inch diameter to nearly two inches. The smallest were found at the upper limits of the range of the pads and the largest were found just above the lower limit. The largest pads were not more than a quarter of an inch in thickness. The colour of the mats was slightly darker than that of the shore. The mats numbered about six per square foot.

The mats do not seem to offer a food supply to many animal species. The only species which has been noted to occur on the mats is the tiny gastropod *Assimania brazieri*, but even this appears to be local in character.

There is field evidence pointing to a considerable seasonal variation in the abundance of the mats. In late summer (March) the mats were noted as far down the shore as the *Zostera* belt but in winter they ended sharply at the commencement of the worm tubes. In the spring the distribution is similar to that in the winter with the exception that the upper limit is higher on the shore. There is not a great seasonal difference in the size of the mats, the pads in the summer being only slightly larger than those in the winter. The number of mats per unit area varies greatly, being very high (more than 20 individuals per square foot) in the spring.

Lying on the floor of the lagoon are clusters of several algae which appear to float about at high tide and lie on the shore when the water has receded. The most common of these is *Enteromorpha compressa* (L.) Grev. The other species are Rhodophyceae. All these species, especially the Rhodophyceae, are in the nature of drift and it is difficult to find the part they play in the intertidal region.

Section B

The Entrance To The Lagoon

As has been noted above that the northern and southern sides of the entrance channel show two sharply contrasting types of shore. From X to Y (Text fig. 2) the northern shore consists of a thin layer of greyish sand overlying black organic mud which in turn lies on a shell bed. Beyond Y the shore is composed of fine ocean beach sand which is backed by low dunes. This sand continues along the rest of the northern shore.

The fauna of the northern shore is similar to that described on Transect 12, and only the differences will be considered here. A feature which is characteristic of this shore is the presence of the crab *Mictyris platycheles* Milne Edwards which is dominant over most of the shore below the *Bembicium* belt and above the *Marcia* belt. The crab is found over the shore between X and Y but some individuals occur on the ocean beach. Also found on this part of shore are *Anapella cycladea*, *Marcia scalarina* and *M. corrugata*. The first of these species is not as common as in the more muddy parts of the lagoon. *Bittium lawleyanum* is not found on the shore, nor is *Assimania brazieri*. The anemone *Anthopleura aureo-radiata* is also absent. Occasional individuals of the lamellibranch *Antigona gallinula* (Lam.) are encountered. *Spisula trigonella* is rare and *Zostera* is absent. The absence of the latter plant is one of the most obvious features of the shore. Due to the lack of shells over most of the shore there are no limpets. The colonies of *Pyura* and the mussels with their *Galeolaria* adherents are also absent. The crabs *Philyra laevis* and *Paragrapsus gaimardii* are both numerous, the former being found at high water. The gastropods *Cominella lineolata* and *Paranassa pauperata* are both plentiful in the sand in this region.

In general, it might be said that the fauna of this section of the shore is in part transitory between that of the ocean beach and the muddy lagoon. There are few surf beach species but there has been a definite elimination in the number of lagoon species. The crab *Mictyris* forms an ecological feature which is not encountered in the lagoon proper. The behaviour of this crab is discussed below.

Mictyris platycheles H. Milne Edwards

This species is very common in vertical burrows over large areas of the sandy shore at both the northern and southern sides of the entrance to the lagoon. The species has a definite preference for a certain type of sand, being found only where that substratum occurs.

(a) On the Northern Side of the Lagoon Entrance

The spit at the lagoon end of the ocean beach is of sand of the same consistency as that of the wave exposed beach but it is populated by a small number of *Mictyris*. The wave exposure found on the lagoon side of the spit is even less than that found within the lagoon and the reason for the poverty of numbers of this species must be found in the substratum. Similarly, to the west of X (Text fig. 2) there are no crabs to be found.

The substratum at the sandy spit consists of a fine white sand typical of surf beaches. There is no substratum of black mud below it. At X there are numbers of dead lamellibranch shells lying thickly on top of and buried in the sand strip which is thin with a thin black mud below it. Between these two places the sand is about 1 inch thick with 3 inches of black mud separating it from the shell bed. Over all this latter area of the shore *Mictyris* is very common. The surface sand is greyish brown in colour, soft and suitable for easy burrowing. The ocean sand is probably too hard to allow easy burrowing and the shells in the more muddy places also offer an obstruction to this habit.

The crabs periodically, at some time when the sand is uncovered by low water, come out of their burrows and move across the sand in large numbers. The general line of movement is parallel to the shoreline. The time of migration is irregular but always occurs at some part of the intertidal period although all of this period is not thus occupied. It is possible that each individual spends only a short time on the surface. There are so many crabs that only a percentage is present at any one time and the number on the surface of the sand is more or less maintained by an unconscious replacement of the satiated individuals which burrow into the sand and await the next tide. McNeill (1926) gives a full description of the genus and described the habits of this species as being similar to those of *M. longicarpus* Latreille. The latter species feeds in horizontal galleries below the surface before coming out on to the top of the sand. Once on the surface the species scrapes the sand and sieves the material for food. In *M. platycheles* as seen at Pipe Clay Lagoon, there is no formation of subsurface galleries. The crab bores its way straight to the surface leaving a round hole such as would be left by a walking stick.

The crab feeds as it moves across the surface of the shore. The chelae are used to scrape sand into the mouth. The movements of the legs of the crab form little balls of sand about one-eighth of an inch in diameter and these are closely spread on the shore. The gut of many crabs examined was full of black mud with little or no sand. This indicates that some subsurface feeding must take place.

The burrows are formed in a similar fashion to that described by McNeill (*loc. cit.*). The crab rotates in a clockwise direction, at the same time lowering one side, usually the left, by scooping with the legs of that side. The crab forms two types of burrow. One is a shallow excavation just below the surface and is made for protection during a migration. On the passing of the danger this burrow is soon quitted. A more permanent burrow is formed for inhabitation during the tidal period. This burrow extends vertically down into the black mud, usually terminating at the top of the shell bed. The crab lives in a slightly enlarged circular chamber at the bottom of the shaft. On the surface the burrow leaves a rosette of disturbed sand so that the surface of the shore is pitted with exit holes and liberally strewn with rosettes and small pellets of sand. The subsurface feeding must take place in this burrow.

The crabs make two sounds on the shore. During migration a noise is made which resembles the patter of large and heavy raindrops on a sandy surface. When buried and possibly feeding a bubbling sound can be heard which resembles that made by a swiftly flowing stream.

The crabs inhabit a broad belt of sand 10 feet below the level of a low 'high high' tide to a level approximately that of 'high low' water. The total width of this belt of the shore is 130 feet and the distance along the shore which is inhabited by the crabs is about ½ a mile. Text fig. 7 shows the density of the species at different levels on the shore. The density was obtained by digging down a foot square of sand as far as the shell bed. It is noticeable that the species becomes numerous quite suddenly and the lower limit of the species is even more sharp. Based on an average density of 7 crabs per square foot there is a population of some 2½ million crabs on this stretch of the lagoon.

Other species found on the same part of the shore as the crab are *Marcia scalarina, Antigona gallinula, Spisula trigonella, Paragrapsus gaimardii, Cominella lineolata* and *Paranassa pauperata.*

In view of the scarcity of records of this species from Tasmania it is worth noting that it also occurs at Seven Mile Beach, Kingston, Blackman's Bay and Orford. McNeill states that the northern coast of Tasmania is the centre of distribution of the species and quotes Smith (1909) as recording the same species from Bridport.

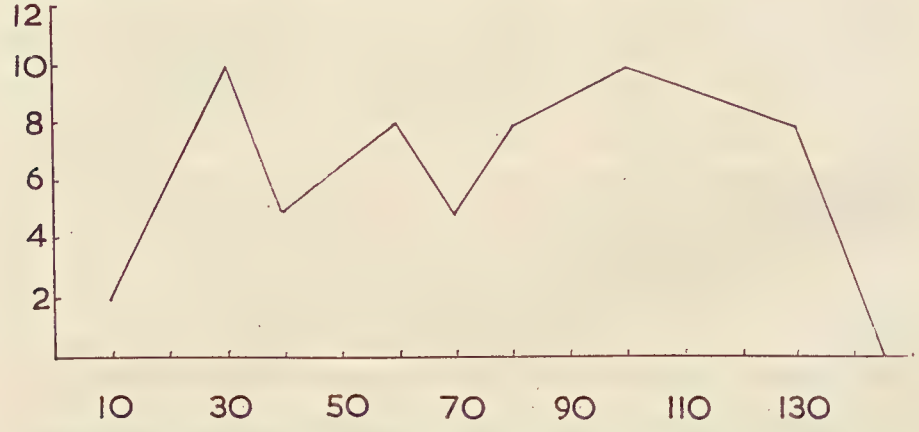

FIG. 7.—Density of population per square foot of *Mictyris* on the shore of Pipe Clay Lagoon. Distances in feet from the level of 'low high' water.

(b) On the Southern Side of the Lagoon Entrance

With the exception of one small area, the crab is not as numerous on this side of the entrance channel as on the northern side. The distribution of the species closely follows the distribution of sand of a similar constitution to that in which the crab is found on the northern side of the channel. The shore from H to I (Text fig. 2) at a distance of 20 feet from the foot of the low cliffs is densely populated by the crabs. The lower limit of this species is 'low low' water. Based on an average density of 6 crabs per square foot, there must be nearly one million crabs on this stretch of shore. The crabs here, as at other parts of the lagoon, avoid water and do not enter the sea. If water has to be crossed they do so rapidly and without stopping. Areas of the shore which are covered with small stones are also avoided. The dislike of stony ground is probably because the crabs find it difficult to feed on rough ground.

On rounding the point at I the foreshore is rocky for about half of its width. The other, lower half, is occupied by *Mictyris.* It was noted that neither *Philyra* nor *Paragrapsus* seemed to make any attempt to feed on the crabs. The predatory

species may become satiated with *Mictyris* at an early time in the intertidal period. At J the soldier crabs die out due to the substratum becoming too muddy. At L the mud gives way very sharply to a patch of sand. On this latter substratum *Mictyris* is extremely numerous, crabs being packed together in a compact mass.

Between L and M the species is only found in very restricted areas of sand. Beyond M the shore is very muddy or stony and the species is not encountered.

The southern shore of the lagoon entrance is very different from the northern. Between I and J the substratum is a yellow-grey sand. Beyond J the sand is replaced by a mud which in turn is replaced by sand at K. At L there is a rich mud patch with sand beside it. Currents deposit a large amount of organic material on this mud patch. At M the shore consists of mud with stones and outcrops of mudstone. This type of shore continues as far as N where there is a shingle beach. Beyond the beach as far as the open sea there are large boulders embedded in mud. Along the shore from L to the sea there are low cliffs of mudstone. The lagoon bottom from J to the sea is of mud.

The fauna and flora of the shore is dominated by the presence or absence of mud. Stones, rocky outcrops and boulders are all covered by a coating of fine silt. Roving species leave very obvious tracks on this incrustation. The presence of such large quantities of mud undoubtedly restricts the distribution of open sea species and so the fauna is composed largely of lagoon forms but with a few open coast species present on the extreme seaward end of the entrance.

Wherever the substratum is suitable the soldier crab *Mictyris platycheles* is found. All the more muddy parts of the shore are populated by *Paragrapsus gaimardii*. At M the surface of the rocks is devoid of macroscopic life, but below stones there are numerous *Paragrapsus*, *Sypharochiton pellis-serpentis* (Quoy & Gaim.), *Plaxiphora costata* (Blainville), *Amaurochiton glaucus* (Gray), *Amphitrite* sp., *Botrylloides* sp., two species of ascidian, *Coscinasterias calamaria* (Gray), *Petrolisthes* sp., and the alga *Codium tomentosum*. On rocks higher up the shore are the barnacles *Elminius modestus* and *Chthamalus antennatus* with the worm *Galeolaria caespitosa* forming considerable growths between the barnacles and the mud covered stones. The holothurian *Stichopus mollis* (Hutton) is found in numbers around 'low low' water mark. This species is only encountered in the summer. Burrowing lamellibranchs are absent from this mud which is very soft. No burrowing forms, other than worms were noted. *Mytilus planulatus* is found on boulders at and above Mean Sea Level. Those individuals living lowest on the shore are infected by the pea crab, *Fabia hickmani* Guiler. The 'patelliform' *Patelloida subundulata*, *Siphonaria diemenensis* Quoy & Gaim. and *S. zonata* Ten.-Woods are all common, the latter in places numbering 12 per square foot. *Austrocochlea obtusa* (Dillwyn) occurs but it is not very common.

Only one oyster, *Ostrea virescens* was found. The whole of the mud and most of the rocks and stones were covered by a thick growth of small Cyanophyceae. These algae undoubtedly form an important part of the food supply of the browsing herbivores.

The shingle bed at N is situated at a place where the current is strongest and where there is scouring action on the bend of the channel. There are no sedentary animals found on the shingle and predatory or browsing species also appear to be absent. Even *Paragrapsus* is not present.

On the large stones at the entrance to the channel the most common organism is the anemone, *Actinia tenebrosa* (Farq.), which has been considered by Blackburn (1937) to be very similar to, if not identical with, the European and African *A. equina*. This anemone also occurs on the rocks at J. In both localities it

frequents the sun sheltered side of rocks. The zonation here is different from that in the lagoon and is a modified form of the rocky coast zonation which can be seen on the Frederick Henry Bay coast. The zoning is . . . *Melaraphe unifasciata* (Gray), *Elminius modestus, E. modestus* with *Chthamalus antennatus, Actinia tenebrosa, Pteria pulchella* Reeve with *Enteromorpha* and *Chordaria cladosiphon* Kutz. The Infralittoral is occupied by various Rhodophyceae which are covered by *Pteria.*

The presence of *Melaraphe* and *Actinia* is undoubtedly an invasion from the rocky coast. The lamellibranch, *Pteria pulchella,* is very numerous in the entrance to the channel forming dense clusters on rocks, algae and waterlogged wood. Some large masses of these molluses are found unattached but are of sufficient size to resist normal wave action. After a gale millions of these bivalves are found washed ashore on the ocean beach. The presence of *Pteria* in the entrance channel is an invasion from the Infralittoral of a sandy beach.

The seaward end of the entrance channel thus shows two separate invasions. In the tidal areas are found species which have wandered in from the rocky coast and in the Infralittoral are species which normally are found in the Infralittoral of a sandy beach.

In the lagoon proper many species are found which also occur on rocky coasts. The most important of these are the mussel *Mytilus planulatus,* the barnacles *Elminius modestus* and *Chthamalus antennatus,* the ascidian *Pyura praeputialis* and the serpulid *Galeolaria caespitosa.*

These species furnish a valuable set of indicators to correlate the faunistic levels within the lagoon with those in other habitats. In some instances it is not possible to use some of the lagoon species on account of their specialized habitat. As an example, the barnacles living on the telegraph pole on the line of the transect are confined to the sun sheltered side of the pole and they do not give a true correspondence of the exposure at that level and at an equivalent level on a rocky coast. The correlation of lagoon faunal levels with those on rocky coasts is treated in the discussion.

At high tide several predatory species invade the lower parts of the tidal region. Foremost among these are fish. No attempt has been made to capture the pelagic fish but some of the bottom feeding species are known. The most common of these, judging from impressions left in the sand, are flounders, probably *Ammotretis* sps. These fish leave impressions in the sand as far up the shore as the lower limit of the *Anapella* belt. Other larger somewhat diamond shaped hollows are made by the less common rays.

The large gastropod, *Fasciolaria australasia* Perry, is rarely found in the Infra *Zostera* zone. The starfish, *Coscinasterias calamaria,* and the holothurian, *Stichopus mollis,* both are frequent invaders.

All these species will be restricted in their choice of food by their limited vertical range.

Discussion

(1) Comparative Notes on the Distribution of Certain Species.

The *Arthrocnemon* scrub is found along all of the western shore of the northern bay of the lagoon. The northern shore of the same bay has a poorly developed scrub. At A the dominant is *Salicornia,* the *Arthrocnemon* plants being reduced in numbers. The *Arthrocnemon* and *Salicornia* marsh is not as well developed in other parts of the lagoon. At C, the marsh is not well developed. In some places there is no marsh at the top of the shore and at D and E it is replaced by a bed of shells and shell fragments.

The lower part of the *Arthrocnemon* scrub is populated by the gastropod, *Salinator solida*. The distribution of this species is controlled to some extent by the amount of water in the marsh. Where there is no marsh, as at D, and therefore little or no seepage on the shore the species is absent. The belt is partly replaced by *Bembicium* but is generally bare of molluscan life. If there is little seepage, as at O, there are only a few of the molluscs on the shore and in the marsh. The marsh at O is the driest in the lagoon. At the marsh at A where there is considerable seepage, the gastropod is very numerous, an average of several counts being 20 per square foot. *Salinator* partially covers itself when exposed to the air by rotating itself clockwise in the sand. The individuals living in the marsh, being independent of the tides do not practise this burying habit.

The *Bembicium* belt is present throughout the lagoon. The belt is usually well developed, but at A, due to a large amount of seepage from the marsh, it is narrow and is soon replaced by *Assimania*. At one place (F) both *Bembicium* and *Assimania* are considerably reduced in numbers due to a concentration of dead *Anapella* shells. The species never attempts to bury itself at low water.

Bittium lawleyanum is distributed throughout the lagoon except in the entrance channels. It does not differ in its tidal distribution from that noted above. In the small bay B, the lamellibranchs *Anapella cycladea* and *Marcia scalarina* are both very numerous. The latter numbers 35 individuals per square foot. In the more sandy parts of the lagoon these species are not as numerous as at Transect 12. It is to be noted that in some small areas *Marcia scalarina* assumes dominance in the lower part of the *Anapella belt*. This is the case in the bay B where there are 35 *Marcia* per square foot, there being only 10 *Anapella* in the same area.

The barnacles found in the lagoon are of two species, *Elminius modestus* and *Chthamalus antennatus*. The former is by far the more common species, being found wherever a suitable substratum offers itself for colonization. Thus, it is encountered on wood, telegraph poles (Plate II), stones and mollusc shells. At the spit at B on the western shore of the lagoon deep water is found close inshore and a rocky substratum is exposed. *Elminius modestus* is found on the rocks and also forms very thick growths on a small jetty nearby. *Chthamalus* is more common on the southern side of the entrance channel. Pope (1945) observes that the latter species likes rocky situations or mollusc shells at high shore levels with some spray. The absence of rocks and spray in the lagoon will probably restrict the distribution of this species.

Algal mats occur at the appropriate tidal levels throughout the lagoon. The mats are most numerous at B. At G, where the Clifton road branches off the lagoon road, the mats occur further up the shore than at other places. The probable reason for this is the direction of the prevailing wind. The effect of this factor will be discussed more fully in connection with the distribution of the *Zostera* beds. In the vicinity of Z_5 the mats are smaller and less numerous than over the rest of the lagoon.

The anemone, *Anthopleura aureo-radiata* (Stuck.), has all but the ring of tentacles and the oral surface buried in sand. It is found living on the shells of *Anapella cycladea* and *Marcia corrugata*. More rarely, it is found on *Marcia scalarina* and *Spisula trigonella*. The most dense population of anemones is found in the small bay B where 20 per square foot is an average figure. The food of this species is largely planktonic. It has been seen to eat worm fragments but rejected isopods.

The *Zostera* beds show a very interesting distribution. Beds are found at Z_1, Z_2, etc. in the lagoon. The beds are found very much closer inshore at the south of the lagoon than at any other place. The Z_1 is close to the point B but

this is due to the depth of water off the point. At the southern end of the lagoon there is no such depth of water and the gradient of the shore is the same as at the northern side of the lagoon. The bed Z_3 occurs only 306 feet from the *Arthrocnemon*. At a tidal period when other beds, particularly Z_1, were under 1 inch of water, the Z_2 bed had 3 inches of water covering it and Z_3 was covered by $1\frac{1}{2}$ inches of water. At the time of examination a strong wind was blowing from the North. It is suggested that the prevailing wind, which is in the North quarter, causes a considerable raising of tidal and faunal levels in the southern part of the lagoon. The difference in levels probably amounts to about 3 inches, which is sufficient, considering the level nature of the lagoon floor, to permit *Zostera* to grow much closer inshore at one end of the lagoon. The algal mats also occur nearer the *Arthrocnemon* scrub at the same end of the lagoon. It is significant that the plants in beds Z_5 and Z_4 are very thin and the plants are not nearly as well developed as in the other beds. The bed Z_2 is the homologue of beds Z_1 and Z_5 but the beds Z_3 and Z_4 are special developments due to the elevation of tidal levels caused by the prevailing wind.

In this connection is to be noted that the beds Z_1, Z_2 and Z_5 are followed by the *Marcia scalarina* belt, beds Z_3 and Z_4 occur within and are followed by the belt of *Anapella cycladea*.

The gastropod *Austrocochlea obtusa* is found plentifully distributed over the lower tidal areas of the lagoon shore. Three varieties of the species are found. The most common is the striped sheltered water form which is the dominant in the *Austrocochlea* belt The small estuarine form is also encountered but it is not common. Although the salinity of the lagoon is above that of sea water this does not seem to produce any notable variations in this variety of the mollusc. The large, ribbed white variety, formerly *A. constricta*, is encountered on the lower parts of the shore. It is usually a feature of wave exposed places. I have found this variety in other wave sheltered places such as Dodge's Ferry. Of the three varieties of *Austrocochlea obtusa* in the lagoon, only the sheltered water form may be considered as being in its characteristic habitat. I am indebted to Miss H. McPherson of the National Museum of Victoria for identification of this species and for drawing my attention to the ecological varieties of the species.

The worm *Galeolaria caespitosa* is found living on shells of mollusca and on stones in the Infra *Zostera* belt. Small pieces of massed colonies of tubes of the worm occur on the sand. These masses are not attached to the substratum and have been broken off thick incrustations. The length of time that the tubes have been detached is a matter of some speculation. Some of the worms in the detached pieces were alive in October, 1950. It has been noted previously (Guiler, 1951) that sometime between December, 1949 and December, 1950 the thick masses of *Galeolaria* found on various parts of the coastline of Tasmania were broken up. The cause of this is obscure. In Pipe Clay Lagoon I have not seen any masses of tubes which correspond to the 'breeding stock' which is left unharmed in other areas. Some tubes are found at J (Text fig. 2) but they do not form such large masses as those at Dodge's Ferry. Assuming that the pieces of worm tube masses found in Pipe Clay Lagoon were disturbed about the same time as at other places, it is of considerable local interest to note that at the time of writing the individuals in these masses are still alive. The wave action in the lagoon must not be sufficient to either bury or break up the worm masses once they have become detached from rocks. This appears to be a special feature of the lagoon. The assumption that the catastrophe which caused the breakage of the worm tubes was general is fairly secure as its results have been observed over about 100 miles of coast. It is doubtful if the worm masses originally came from the

lagoon. There are not sufficient areas of rock suitable for intense colonization except at J which is occupied by small, old colonies which have not been broken up. The broken masses of worm tubes were probably smashed up on the wave exposed coast and were washed into the lagoon.

Roving species such as the gastropod *Cominella lineolata* and *Paranassa pauperata* are found throughout the lagoon. The latter species occurs at all tidal levels but the former is only found at the lower levels of the shore. The crabs *Paragrapsus gaimardii* and *Philyra laevis* are also found at all tidal levels. The latter species is only evident at high water, only one specimen being found buried during the intertidal period.

The most common birds found feeding on the shore are oystercatchers, *Haematopus ostralegus* L., silver gulls, *Larus novaehollandiae* Stevens, black swans, *Chenopis atrata* (Latham), whitefronted herons, *Notophoyx novaehollandiae* (Latham), the Caspian tern, *Hydroprogne caspici* (Pallas), and dotterels.

(2) General

The effect of climatic factors is considerably reduced by the nature of the lagoon shore. The shore, as noted above, is fairly level and a large amount of water is retained on the sand as the tide recedes. The sand is always very moist, even at low water in summer time, and low water species such as *Austrocochlea obtusa* are found as far up the shore as high water level. The high density of population in the belts immediately above the *Zostera* is undoubtedly assisted by the high moisture content offering extended feeding time and protection from dessication. In the bay at B there were 35 *Marcia scalarina*, 10 *Anapella* and 20 anemones per square foot. The *Zostera* bed being raised an inch or so above the level of the shore causes water to be imprisoned behind the bed at low tide. This lake increases the amount of water retained on the shore.

The warm temperatures of shore waters of the lagoon during the summer is probably of considerable importance in keeping the lagoon bottom dwelling forms from migrating freely into the lower tidal levels. In winter, temperature does not operate as a controlling factor for Infralittoral forms due to the off-shore migration of most mobile forms during that period of the year.

The fauna of the lagoon can be compared with that of rocky coasts and the correlation of faunal levels is shown in Table I. The relations of the faunal levels in different habitats will be discussed more fully in a future paper and this Table must be regarded as an interim report on the subject.

The relationship between the Upper Shore and the Supralittoral Fringe and the Supralittoral is fairly close, the *Arthrocnemon* belt corresponding to the *Melaraphe* belt of a wave exposed coast. The upper limit of the Supralittoral fringe on exposed coasts is usually fairly well defined but in the lagoon the only obvious difference is the elimination of the gastropod *Salinator solida*. The range of this mollusc may be extended by the presence of water in the marsh. The *Arthrocnemon* scrub, or *Salicornia* mat, corresponds in most part to the Supralittoral. The upper limit is not clear as the plants merge into the terrestrial maritime plants.

The lower part of the *Arthrocnemon* scrub corresponds to the saltings described by Curtis and Somerville (1947) at Boomer Marsh. In comparison with the latter area it can be noted that *Arthrocnemon* is not as plentiful at Boomer as at Pipe Clay Lagoon. Curtis and Somerville further note that the alga, *Hormosira banksii*, is found living on mussels which are buried in the mud in the Infra *Zostera* zone. This alga does not occur at Pipe Clay Lagoon.

TABLE I.

The zonation at Pipe Clay Lagoon compared with that on other types of coast in South Tasmania

	Lagoon		Semi-exposed Coast	Exposed Coast	Sheltered Bay	% Exposure
Supra Littoral	*Arthrocnemon*	UPPER SHORE	Lichens	Lichens	? Bare	100
Supra Littoral Fringe	*Arthrocnemon* + *Salinator*		*Melaraphe*	*Melaraphe*	*Melaraphe*	70-100
Mid Littoral	*Bembicium*	SUPRA ZOSTERA	*Bembicium* (local)	Absent	? local	60-90
	Bittium		Barnacle	Barnacle	Barnacle + *Austrocochlea*	27-88
	Anapella		*Galeolaria*	*Catophragmus*	*Galeolaria*	18-71
	Zostera	ZOSTERA	*Patelloid (Brachy odontes)*	*Patelloid*	*Hormosira* &/or *Mytilus*	7-60
	Marcia		*Patelloid* *Mytilus*	*Corallina*	*Corallina*	0-26
Infra Littoral Fringe	*Austrocochlea*	INFRA ZOSTERA	*Laurencia* & *Lessonia*	*Sarcophycus*	*Cystophora*	0-2
Infra Littoral	*Pyura*	LAGOON BOTTOM	?	*Macrocystis*	*Cystophora*	0

The Mid Littoral of Stephenson & Stephenson (1949) appears to correspond to the Supra *Zostera*, *Zostera* and part of the Infra *Zostera* zones. On semi-exposed coasts the *Bembicium*, barnacle, Patelloid and *Mytilus* belts form the Mid Littoral.

The *Bembicium* belt is very well developed in the lagoon and occurs all round the upper Supra *Zostera* zone. The belt may partly replace the *Salinator* belt where there is little or no seepage from the land above the shore. On semi-exposed coasts the belt is developed locally in places where wave action is not strong. The belt is absent on wave exposed coasts. It is absent from sheltered bays. In view of its presence in the lagoon and on semi-exposed coasts it might reasonably be expected that the species would occur in sheltered bays. The ecology of sheltered bays has not been investigated fully but the species is definitely absent from Coles Bay (Guiler, 1951).

The barnacle *Elminius modestus* does not form a belt in the lagoon but is found on stones, telegraph poles and other such objects. By making use of the range of this species it is possible to determine that all the *Bittium* and most of the *Anapella* belts can be placed in a strip corresponding to that occupied by barnacles on exposed or semi-exposed coasts. The lower *Anapella* belt is equivalent to the *Galeolaria* belt of semi-exposed coasts and the *Catophragmus* belt of exposed coasts. The Patelloid belt of exposed coasts is approximately equivalent to the extreme

lower end of the *Anapella* belt. The small limpet, *Patelloida subundulata*, is found as far up the shore of the lagoon as the *Bembicium* belt but the range of this species is not equivalent to that of any species found on an exposed coast.

The tube worm *Galeolaria caespitosa* is found at different levels in various places in the lagoon. At the southern side of the entrance channel the species is found above mussels on the shore. On the transect it would appear that the equivalent level is somewhere in the lower part of the *Anapella* belt. No tubes are found there but this may be due to the very severe limitation of suitable habitats for *Galeolaria*. The *Anapella* belt is very broad and probably several of the belts found on rocky coasts are represented by the one large belt in the lagoon.

The *Zostera*, neglecting beds Z_3 and Z_4, appears to correspond in tidal levels to the mussel *Brachyodontes rostratus*, which is found living in the *Zostera* beds. The mussel has been noted to form an incomplete band on semi-exposed coasts in the *Patelloid* belt. (Guiler, 1950). The level of 'dodge' tides at Blackman's Bay is at or about the middle of the *Galeolaria* belt. At similar tides at Pipe Clay Lagoon the *Zostera* can just be seen as a dark line on the surface of the water. The *Zostera* bed projects about 1 inch above the general level of the lagoon shore and allowing for this fact it is considered that the *Zostera* is at an equivalent level to that occupied by *Brachyodontes rostratus*. In sheltered bays *Zostera* usually occurs at a much lower level, often below tide marks. The reason for this is not yet clear.

The *Marcia corrugata* belt corresponds to the *Mytilus planulatus* belt of semi-exposed shores and the *Corallina* belt of exposed shores. The belt may be exposed at 'low high' tide.

The *Austrocochlea* belt is only fully exposed at 'low low' tides. In winter the tide rarely recedes far enough to allow examination of this belt. It is thus the lagoon representative of the Infra Littoral fringe.

The ascidian *Pyura praeputialis* is found on the Lagoon Bottom. Some groups of individuals may be exposed at an abnormally low tide but a normal 'low low' tide does not expose this species.

The salient feature of the comparison of the zoning on coasts with some degree of wave exposure with that in the lagoon is the number of belts on the former coasts which are represented by *Anapella* in the lagoon. As noted above, these correlations will be fully discussed in a future paper.

The food of the ecologically important organisms in the lagoon has been noted. The notes are based on observations of food catching, gut examinations and the known food habits of the animals or allied species. A possible food chain is given (Text fig. 8).

Within the lagoon there are three faunal types of sand. The ocean beach with a poor fauna, a *Mictyris* sand and a *Paragrapsus* mud. After a few visits to the lagoon it is possible to differentiate with considerable accuracy between these types, and consequently to predict the fauna living in the sand.

All the molluscs named in this work were checked against specimens in the May collection in the Tasmanian Museum.

Acknowledgments

This work was carried out under a Commonwealth Research Grant to which I am indebted for travelling expenses. To Mr. J. L. Hickman, B.Sc., and Mr. R. H. Cruickshank, B.Sc., I extend my thanks for assistance during the initial measurement of the transect. I am grateful to Miss H. MacPherson of the National Museum of Victoria for the identification of *Salinator*, *Bembicium* and

Austrocochlea. I am indebted to Dr. J. Pearson, Director of the Tasmanian Museum, for permission to check my own mollusc identifications. Miss H. Gulline, B.Sc., of the Botany Department of the University of Tasmania, provided me with a report on the *Arthrocnemon* scrub and this forms the basis of the description of that part of the shore. I owe my thanks to Professor V. V. Hickman for his encouragement, interest and checking of the paper.

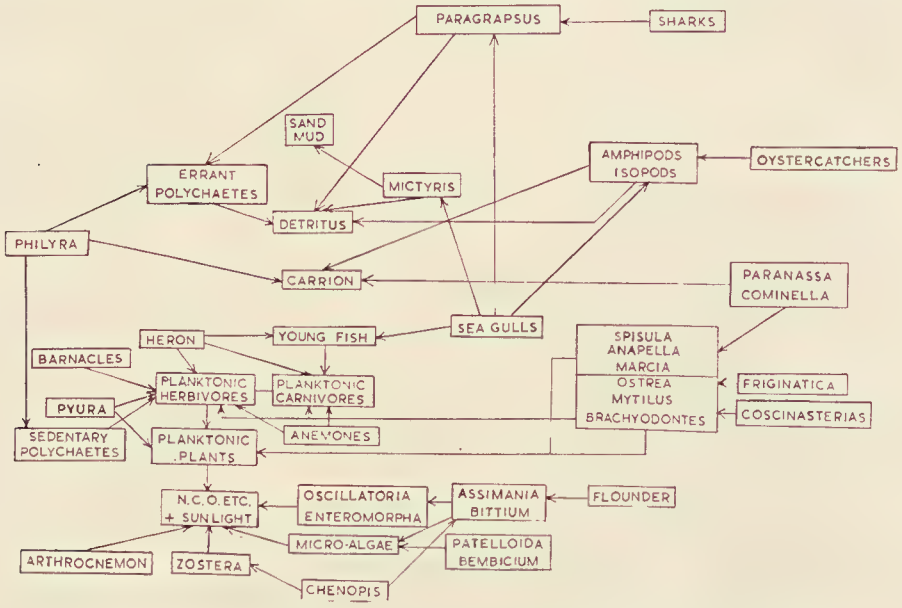

FIG. 8.—Suggested food-chain for intertidal organisms in Pipe Clay Lagoon.

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Fig. 1.—Aerial photograph of the northern bay and centre of Pipe Clay Lagoon.
Published by courtesy of the Tasmanian Government Lands and Surveys Department.

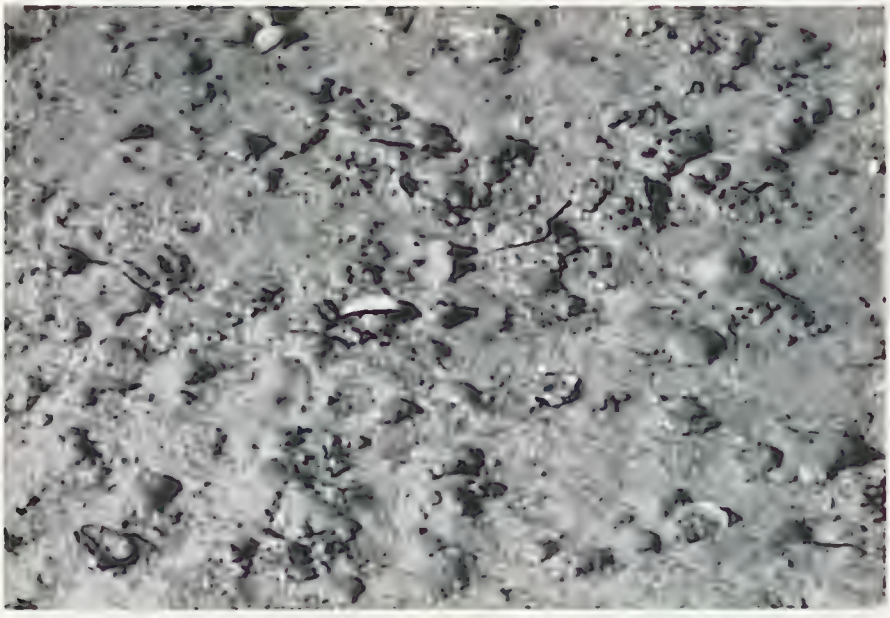

FIG. 1.—Algal mats on the shore at Pipe Clay Lagoon (October).
[*Photo. T. McMahon.*

FIG. 2.—Barnacles on the sun-sheltered side of a telegraph pole at Pipe Clay Lagoon.
[*Photo. T. McMahon.*

Pap. & Proc. Roy. Soc. Tasmania, 1950 (15th December, 1951)

Notes on the Intertidal Ecology of the Freycinet Peninsula

By

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(Read 7th November, 1950)

WITH 3 PLATES AND 4 TEXT FIGURES

Summary

This paper is a continuation of the study of the features of the intertidal region in Tasmania. The areas so far studied were at Blackman's Bay and Pipe Clay Lagoon. The eastern coast at Freycinet Peninsula forms a more rigorous environment than the Blackman's Bay area due to higher and lower extreme temperatures. The eastern coast of the peninsula is exposed to heavy wave action but the western shore is sheltered. Transects on both sides of the peninsula are described and compared. The algae of the Infralittoral fringe are very different on the two sides of the peninsula, the Tasman Sea side being dominated by the large *Sarcophycus* and *Macrocystis* while the sheltered shore is populated by *Cystophora*. There are differences in the animal populations of the two shores but these are not as profound as might be expected. Forms characteristic of the sheltered western coast do not extend to the eastern shore but many forms found on the east coast are found on the sheltered shore. A general poverty of barnacle population is noted and is attributed to the substratum of granite rather than to any climatic factor.

A brief comparison of the features of this coast with those seen at Blackman's Bay is given. Notes on the distribution of several species in Tasmania and New South Wales are added. The possible ecological affinity of the wave exposed coasts of Tasmania with those of western South Africa is mentioned.

Introduction

This paper is the third of a series on the features of the intertidal region in Tasmania and deals with the ecology of Freycinet Peninsula. The first paper described the conditions on semi-exposed coast in southern Tasmania (Guiler, 1950). Other areas of the coasts of Tasmania will be considered in separate papers.

The peninsula is about 130 miles from Hobart (see fig. 1.). The landward part of the prominence is accessible in places but the distal end is more difficult of approach. Beyond the Quarries and Wineglass (Thouin) Bay the shore is only accessible by poor tracks or by arduous scrambling over rocks. For this reason no detailed work has been carried out on the southern end of the peninsula. A small expedition would be necessary to fully examine the coast hereabouts.

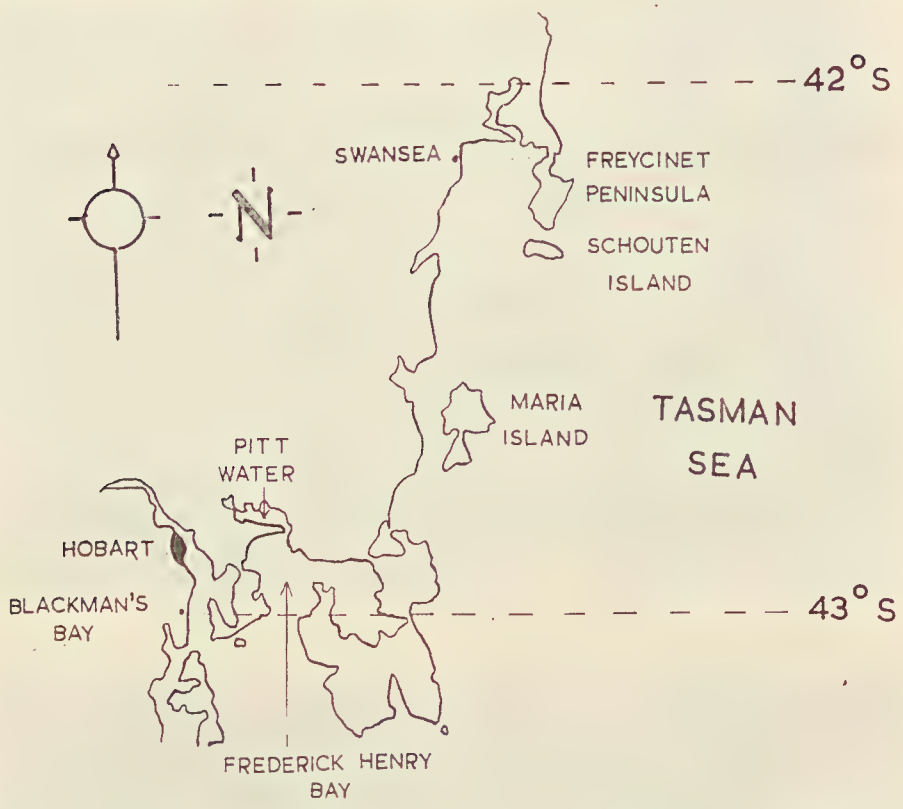

FIG. 1.—Outline of the East Coast of Tasmania showing the position of Freycinet Peninsula.

Transects were examined at Coles Bay, Honeymoon Bay and Sleepy Bay. Examinations for comparison were made at Wineglass Bay, The Fisheries, The Quarries and at several places beyond the Quarries. (See fig. 2).

The terminology used will be the same as that employed in the first paper of this series and follows that of Stephenson and Stephenson (1949). The tidal terminology is that of Chapman (1938).

Freycinet Peninsula lies at approximately the middle of the east coast of Tasmania. The peninsula runs parallel to the general line of the coast. To the west and south the peninsula is separated from the mainland by Oyster Bay and to the east lies the Tasman Sea. There are several lagoons (fig. 2) at the north end of the peninsula where it joins the mainland. It is not proposed to examine the ecological features of these specialized habitats. It is hoped to study the ecology of lagoons at a future date. South of the peninsula are Schouten and Maria Islands. Schouten Island is separated from the peninsula by a narrow strait but Maria Island is 35 miles away. The peninsula shows two major ecological types of coast. The East is exposed to full wave action and the West is sheltered and only experiences the effects of winds and waves blowing across shallow Oyster Bay. On both coasts are varied habitats, ranging from surf beaches and wave exposed coasts to sheltered inlets.

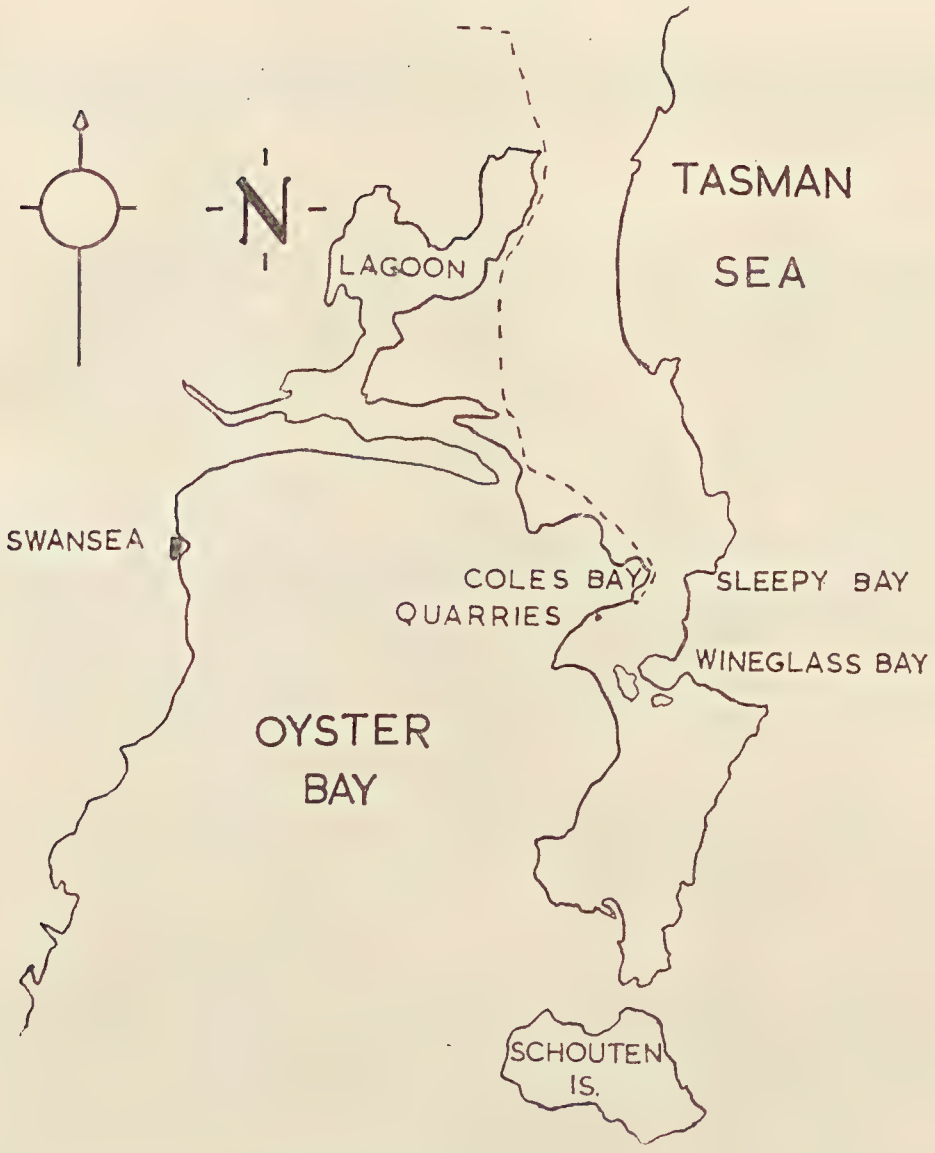

FIG. 2.—Map of Freycinet Peninsula showing most places mentioned in the text. Scale: 8 miles to the inch.

PHYSICAL ENVIRONMENT

(1) *Tides.* There are no tidal data available for the east coast. From observations made on the shore the tides are of approximately the same magnitude and general behaviour as those encountered at Hobart. The exposure figures calculated from the Hobart Recorder may be applied to the east coast but must be considered as very approximate.

(2) *Climatic Factors.* It is generally accepted that the east coast is warmer than Hobart. Examination of the records of the Hobart Weather Bureau reveals that a slightly different state of affairs exists. Swansea is the nearest recording station from which records for a long period are available. Some records are

available from Swanwick at the entrance to the lagoons mentioned above. These latter records are only for a short period and do not give a true picture of the climatic conditions. The climatic data have been taken from the Weather Bureau (1936) and are shown in Figs. 3-4.

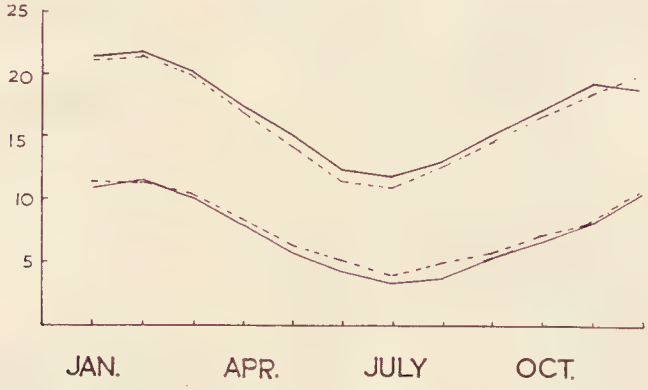

FIG. 3.—Mean monthly maximum and minimum temperatures Swansea (unbroken line) and Hobart (broken line) over 37 and 66 years respectively. The upper pair of curves show the mean monthly maximum temperatures and the lower pair the mean monthly minimum temperatures.

FIG. 4.—Average rainfall at Swansea (unbroken line) and Hobart (broken line) over the last 58 and 68 years respectively.

From the above figures it can be seen that Swansea has a slightly greater temperature range than Hobart but the rainfall is slightly less. Freycinet Peninsula is possibly dryer than the mainland Swansea. The incomplete figures for Swanwick do not support this view but the observations of residents on the peninsula mention that it may be raining in Swansea and quite dry in Coles Bay.

In particular we might note that the east coast experiences warmer temperatures in the summer yet colder in the winter.

(3) *Sea Temperatures.* There are no sea temperatures available. Observations taken over a period of two weeks at Coles Bay in February, 1950, showed an average temperature of 16·8°C. Some records taken at Sleepy Bay in the Tasman Sea were up to 1°C colder than readings taken shortly later at Coles Bay.

Temperatures taken in the sea just off-shore showed the influence of hot rocks and sand. The readings were taken on the afternoon of 6th February, 1950 in the Coles Bay area. The results are shown in Table I.

TABLE I

The influence of warm rocks and sand on sea temperatures at Coles Bay, Freycinet Peninsula. Normal surfaces sea temperature was 15·25°C.

Distance off-shore	*Off Rocks*	*Off Sand*
3 feet	16·75°C.	18·75°C.
10 yards	16·25°C.	17·25°C.
30 yards	15·3°C.	15·25°C.

In spite of the small tidal range the effect of warm sands and rocks on the sea temperature is felt for a distance of nearly 30 yards off-shore. Intertidal organisms are thus bathed during warm days in sea water which may be up to 3° C above normal sea temperatures. It might be stressed that the area considered does not have a closed water circulation. In such a place, e.g. a lagoon, the water temperature may be expected to be greater.

(4) *Currents.* The warm Notonectian Current runs some distance off-shore down the east coast of Tasmania. The full behaviour of this current is not known. In particular, it is not known whether the current actually runs on the coast during the summer months. Certain organisms such as *Physalia* and *Mola,* characteristic of warm seas are found in Tasmania in the summer the former being picked up in numbers on the east coast beaches. Whether they are deposited by the main current or other agencies is not clear. A series of temperature readings taken at Coles Bay when compared with Hobart sea temperatures failed to show any significant difference between the temperatures at these two places.

Fischer (1940a) following Dannevig (1907) notes that the Notonectian current runs along the Tasmanian coast at some distance offshore.

(5) *Geology.* The cliffs and beaches of the peninsula are composed of red granite or its derivatives. On the wave exposed east coast the rock forms steep cliffs but on the west shore the cliffs are either absent or low. At the south end of the peninsula the cliffs are high on both exposed and sheltered coasts. The beaches are formed of either boulders or quartz-felspar shingles or sand. At no place are rock platforms found.

(6) *Wave Action.* During easterly gales the wave action on the east coast of the peninsula is severe. The exposure factor can be expressed as O. (1-10). 4. 2,3. The derivation of this factor has been explained in Guiler (1950, pp. 169-171). At some places the effect of the waves is reduced by the presence of large beds of kelp. It is difficult to evaluate the full effect of these on the intensity of wave action on the shore. The continental shelf does not seem appreciably to diminish or break up the ocean swell.

Discussion

The climate of the east coast, based on Swansea records, is more extreme than that at Hobart. The maximum temperatures throughout the year are higher and the minimum temperatures are lower than in the Derwent area. The annual rainfall is nearly the same as at Hobart, but the distribution throughout the year is different. Swansea has appreciably less rain than Hobart during the period August to November but a heavier rainfall in June and July.

It has been noted previously (Guiler, 1950) that the months of December, January and July are times of great stress for intertidal organisms in southern Tasmania. July is the coldest month of the year on the east coast and is colder than at Hobart. January and February are months of considerable heat, both being warmer than at Hobart. The heaviest rainfall occurs in June and is much greater than any encountered in the Hobart area during that month.

The above climatic factors combined with the tidal factors considered in the first paper of the series (pp. 155-163) gives a more rigorous intertidal habitat for organisms than at Hobart. The lowest temperatures are encountered when the 'low low' water is the early morning tide and the highest temperatures occur when the afternoon tide is the 'low low'. These temperatures are below and above the respective Hobart figures.

Zonation

(1) On the East Side of the Peninsula

The transects considered here have been numbered consecutively with those of the paper on the ecology of the Blackman's Bay area (Guiler, 1950.).

Transect 9

Station	On the rocks at the head of Sleepy Bay, below the track from the Chateau.
Date	February, 1950.
Type	Wave exposed rocky coast.
Maximum wave exposure	a (1-10) 4, a, 2. The wave exposure is modified by the off-shore kelp beds. This influence is difficult to evaluate.
Description	The transect is on the sloping rocks in the more sheltered part of the bay. In easterly gales the wave action may be severe.
Geology	Red granite.
Tidal data	Approximately similar to those noted for Hobart.
Physical environment	See above.
Zonation	The basic zonation of this transect is as follows:—*Melaraphe unifasciata* (Gray). Balanoid zone. Patelloid zone, *Corallina* zone, infralittoral fringe with *Sarcophycus*.

(i) The Supralittoral Zone

Most of the Supralittoral is occupied by bare rock. A band of orange lichens commences immediately above the *Melaraphe* zone. A few small *Salicornia* plants are found in clefts in the rock.

(ii) The Supralittoral Fringe

The only common macroscopic organism in this zone is the Littorinid *Melaraphe unifasciata*. This mollusc is fairly evenly distributed over a band zone eight feet in vertical width. The species is found in clefts and hollows in the rocks and also in sun sheltered places.

(iii) The Midlittoral Zone

There are three belts in the Midlittoral. These are a barnacle belt, followed by one of *Patella*-like organisms which in turn is replaced by a *Coralline* belt. The barnacles follow immediately below the Supralittoral fringe. There is the usual narrow mixed belt of barnacles and gastropods at the junction of these two zones. The lower limit of the Midlittoral is marked by a belt of *Corallina*. Between the *Corallina* and the barnacles there is a strip of *Patella*-like organisms. This latter belt is narrow and is separated from the barnacle belt by a narrow band of barnacles, 'patelloids' and a few small tubes of the worm *Galeolaria caespitosa* (Lam.). This latter mixed belt is nine inches in vertical height.

The barnacles inhabiting this zone are all very small, being rarely more than 2·0 mm. in height and 4·0 mm. in breadth. The dominant species are *Elminius simplex* Darwin and *Chthamalus antennatus* Darwin. The density of population in this zone is very low. The barnacles are confined to cracks and other sheltered situations. In several places barnacles occur in closely packed masses but these populations do not occupy large areas and consequently there

are not many individuals in each cluster. The reason for the population of barnacles in these few places is not at all clear. Other non-populated areas seem to be just as suitable as many of the chosen areas. There is a slightly greater number of populated areas on sun-sheltered surfaces.

A few small mussels, *Brachyodontes rostratus* (Dunker), are found in cracks in the rock at the same level as the serpulid worm *Galeolaria caespitosa.*

The Patelloid belt is not fully developed in this transect. The species are the same as in the following transect but not as numerous or as large in size. The belt is described more fully in Transect 10.

The few species noted above represent the sum total of the fauna encountered in the upper Midlittoral on the transect. There were no algae. On a quick examination from a few yards away the rock above the worm tubes appears to be devoid of any inhabitants and the few species which occur are all found in semi-cryptic places. (Plate III illustrates to some extent the bareness of the shore.)

Immediately above the kelp is a *Coralline* belt. The algae are the dominant forms found on this part of the shore. *Lithothamnia* (meaning all *Lithothamnion*-type-forms), *Laurencia* sps., *Corallina cuvieri,* some *Ulva lactuca* L. and a few Patelloids, mostly *Siphonaria diemenensis* Quoy and Gaim. are the most common species. The most common barnacle is the large *Catophragmus polymerus* Darwin with a few *Elminius simplex.* Some *Galeolaria* tubes are also found but they are scattered and do not form a continuous incrustation on the rock. The mussel, *Mytilus planulatus* Lam. occurs in the belt but the specimens are small in size and few in numbers. The mussels do not form beds or aggregated masses.

(iv) The Infralittoral Fringe

The Infralittoral fringe furnishes the most striking part of the intertidal region. The large Bull Kelp *Sarcophycus potatorum* (Labill.) Kütz, is very prominent at 'low low' water and forms a sharply defined band running all around the shore. (Plate I).

This alga occupies a considerable amount of the rock space. Its holdfasts do no offer the same habitat for organisms as do the branching holdfasts of *Laminaria* sps. (Plate I.) The illustration in Plate I. is not typical of the traverse. In the area photographed a horizontal ledge below the level of the *Sarcophycus* offers a substratum which has been colonized by a modified *Coralline* population. On the line of the transect there are a few other algae in the Infralittoral fringe, though *Xiphophora* sp. and *Splanchnidium rugosum* (L.) Greville are found. Living near the base of one *Xiphophora* plant were several individuals of the interesting 'patelliform' isopod *Amphoroidea elegans* Baker. All other available *Xiphophora* plants were examined for this species but none of them had specimens of the crustacean dwelling on them.

Transect 10

Station	To the South of the previous transect at Sleepy Bay.
Date	February, 1950.
Type	Exposed rocky coast.
Maximum wave exposure	o. (1-10) 4, a, 3.
Description	From the seaward end of the terrain in Plate III, the transect runs along the rocks to the north of the small island in Sleepy Bay. The island does not shelter the shore from wave action.
Geology	Red granite.
Tidal data	Approximately similar to those noted for Hobart.
Zonation	As in Transect 9.

(i) The Supralittoral Zone

Most of the Supralittoral zone in this transect has a poor lichen population. There are no other species in the zone. At the landward end of the transect are vertical cliffs which carry sparse patches of orange lichens. Most of the Supralittoral which was examined (about 40 feet) lies in a roughly horizontal plane at the foot of these cliffs. The cliffs are in such a position that they do not shelter the zone from the sun.

(ii) The Supralittoral Fringe

As in Transect 9, the Supralittoral fringe is populated by the littorinid *Melaraphe unifasciata*. This gastropod does not reach as high on the shore as in Transect 9. The possible reason for this is discussed later.

(iii) The Midlittoral Zone

The topmost belt of this zone is occupied by barnacles of which the dominant species is *Elminius simplex*. In the lower parts of the barnacle belt there are a few limpets, *Patelloida cantharus* (Reeve). A few small *Brachyodontes rostratus* and *Galeolaria caespitosa* are found in cracks in the rocks. Small specimens of the barnacle *Catophragmus polymerus* inhabit cracks in the lower part of the barnacle belt.

On a sloping face at the same level as the lower barnacle belt, but with a greater degree of wave action the population is composed of the same species as noted above but the *Catophragmus* barnacles are larger and more battered in appearance.

The Patelloid belt is well developed. The dominant forms are *Siphonaria diemenensis* and *Patelloida alticostata*. *Patelloida cantharus* and the large *Cellana limbata* (Philippi) are also common. Living among the limpets are a few *Tetraclita purpurascens* (Wood) and numerous *Catophragmus polymerus*.

The lower Patelloid belt grades off into the *Coralline* belt, which in turn is replaced by the *Sarcophycus* belt. In the latter case the line of demarkation between the belts is very sharp.

The lower parts of the Midlittoral are dominated by various *Coralline* algae. *Corallina cuvieri* Lamouroux is the most numerous of the algae and forms a thick carpet over most of the belt, but is particularly well developed in the lower areas. A large coral alga, not yet identified, forms a very important habitat for small organisms in the *Coralline* belt as a whole (Plate II). This alga occurs in two forms, both of which are to be seen in the plate. The more common and obvious form is regular and dome shaped, being up to three inches in height. The other form is encrusting and of irregular shape. The latter is to be seen to the lower right of the large chiton in the plate. Both forms constitute the habitat for Sphaeromid isopods, amphipods, errant polychaetes and the small mollusc *Lasaea australis* (Lam.). This latter species is very numerous and is to be found in spaces inside the algal mass.

Also found in the *Coralline* belt are some barnacles, mostly *Catophragmus polymerus*, numerous limpets of the species *Cellana limbata* and *Patelloida alticostata* with the pulmonate *Siphonaria diemenensis*. Three species of chiton are common, namely *Plaxiphora albida* (Blainville), *Ischnochiton evanida* (Sowerby) and *I. mayi* Pilsbry. The largest of these is *Plaxiphora* but the other species are more numerous.

(iv) The Infralittoral Fringe

The Infralittoral fringe is dominated by the Bull Kelp, *Sarcophycus potatorum*. Even during calm weather the sweeping action of the fronds of this alga are continuous and strong. In the lower levels of the Infralittoral fringe *Macrocystis pyrifera* (Turn.) Agardh., *Xiphophora* sp. and other smaller species can be seen. Owing to the depth of the water and the strong swell they are very difficult to collect. The small gastropod *Calliotrochus legrandi* (Petterd) has been collected on the various algae.

On other parts of the shore where there are sheltered places with loose boulders a varied fauna is to be found. Many of the species are incrusting and constitute the hypobiose of Gislén (1930). Common species are *Hymeniacidon perlevis* (Montagu), *Sycon gelatinosum* (? var. whiteleggei), two species of Euceratosa, *Haliotis noevosum* Martyn, *Cellana limbata, Patelloida alticostata, Lomis hirta* (Lam.) *Idotea caudacuta* Haswell, isopods and amphipods, a pycnogonid of the genus *Nymphon, Boltenia pachydermatina* Herdman, an ophiuroid, *Chaetomorpha* sp., and encrusting *Codium* and numerous *Lithothamnion* sps.

A few individuals of the ascidian *Pyura praeputialis* (Heller) are found in the more sheltered places. On wave exposed surfaces the species is rare.

The continuous intensity of the heavy swell in the area is shown on a small island just off-shore at Sleepy Bay to the south of the transect. The island is cleft by a fissure which is some seven feet above the level of 'low low' water. On calm days at low tide the swell surges through this cleft. The cleft is populated by numerous plants of *Sarcophycus potatorum* with a modified Infralittoral fringe fauna and flora. (Plate II.)

(2) On the West Side of the Peninsula

Transect 11

Station	On the rocks below the Chateau, Coles Bay.
Date	February, 1950.
Type	Sheltered rocky coast.
Maximum wave exposure	s (0-8) 2. b, 3.
Description	The transect runs at right angles to the shore line, 20 yards to the east of the landing stage below the Chateau.
Geology	Red granite.
Tidal data	Approximately similar to those noted for Hobart.
Zonation	*Melaraphe unifasciata;* barnacle belt; *Galeolaria caespitosa; Hormosira banksii; Corallina* belt; *Cystophora* in Infralittoral fringe.

(i) The Supralittoral Zone

There are no lichens or other macroscopic organisms inhabiting the Supralittoral. The zone is wide and ends abruptly in a sandy soil.

(ii) The Supralittoral Fringe

As in all other transects the Littorinid *Melaraphe unifasciata* is the dominant organism on this part of the shore. The pure *Melaraphe* belt is very restricted, its total vertical height being only four inches. This restriction of the upper limit of the gastropod is to some extent aggravated by the conformation of the granite which is rounded and does not offer any cracks as shelter from the sun.

(iii) The Midlittoral Zone

The zonation of the Midlittoral is very different from that seen at Sleepy Bay. The barnacles, *Elminius simplex* and *Chthamalus antennatus* form a wide mixed belt with *Melaraphe*, ultimately passing into a pure barnacle belt. In sun sheltered

places in these belts are found a few very small *Brachyodontes rostratus*. Large numbers of the Trochid *Austrocochlea concamerata* (Wood) are also found in the same places as the mussel. In gulleys at the lower end of the barnacle zone are large numbers of the chiton *Sypharochiton pellis-serpentis* (Quoy and Gaim.), with numbers of tubes of *Galeolaria caespitosa*, a few *Brachyodontes rostratus* and some *Tetraclita purpurascens* (Wood).

The mussel *Brachyodontes rostratus* forms a strip just above the lower limits of the barnacle belt. The *Galeolaria* belt is of considerable width but only seven inches in vertical height. The worm tubes are not as closely packed as in Transect 1 at Blackman's Bay and are also smaller in size.

Hormosira banksii (Turn.) Decaisne follows below the serpulids. There is no mixed *Hormosira-Galeolaria* belt. The alga does not form a dense growth in the nature of a *Hormosirctum*. At the lower end of the *Hormosira* belt there exists a narrow mixed belt of *Hormosira* with *Corallina*. This is followed by a *Coralline* belt.

The fauna of the *Coralline* belt is poor. The alga forms a dense covering to the rock and does not permit the existence of colonial or gregarious animals. Very few animals, mainly isopods, are found in the *Corallina*.

In all of the Midlittoral the fauna is poor both in numbers and species. Other than the index species mentioned above, there are very few forms to be found on the shore.

(iv) The Infralittoral Fringe

The dominant algal forms in the Infralittoral fringe are the two species *Cystophora torulosa* (R. Br.) J. Agardh. and *Caulocystis uvifera* (Ag.) J. Agardh. These algae form a dense 'scrub' which extends down the rocks to the bay bottom of sand and forms the habitat for a large fauna.

The 'lithothamnia' are very poorly developed in the Infralittoral fringe. Among other algae present are *Seirococcus axillaris* Greville, *Griffithsia ovalis* Harvey, *Phyllospora ? comosa* (Labill.) C. Agardh. and *Caulerpa sedoides* (R. Brown) C. Agardh. In restricted areas, none of which occur on this transect, are patches of *Zostera nana* Roth. and *Cymodocea antarctica* Endl. The Honeymoon Bay Beaches have several small patches of *Cymodocea* and just to the west of this transect there is a patch of *Zostera*. The *Zostera* does not form a Zosteretum. At the jetty at the opposite side of Coles Bay from the transect there is a large bed of *Zostera*, which, on examination from a boat at low water, seems to have a characteristic fauna. Some *Ulva* and *Enteromorpha* are found in isolated patches on the shore.

Compared with the east side of the peninsula the absence of *Sarcophycus potatorum* is most striking. In deeper water further along the coast past the Quarries, a few small *Sarcophycus* plants are found.

The dominant animal in the *Cystophora* is the gastropod *Cominella lineolata* (Lam.). Other common forms are *Subninella undulata* Solander, *Cantharidus eximius* (Perry), *Phasianella australis* (Gmelin), but only one specimen of the mutton-fish *Haliotis nocvosum* (Martyn): *Amblypneustes ovum* Lam. and *Strongylocentrotus erithrogrammus* (Val.) are both numerous in the weed. The cephalopod *Polypus variolatus* (Blainville) is fairly common, one individual being noted with a body length of 18 inches. Crustacea Decapoda are very poorly represented. *Lomis hirta* (Lam.) is the most common species and *Naxia spinosa* (Hess) is also frequent. There must be many more crustaceans but due to the weed being covered

by water during the collecting periods many of these must have escaped capture. Only the upper parts of the *Cystophora* belt are uncovered at any 'low low' tide. The only fish captured was the pipefish *Leptonotus semistriatus* (Kaup).

Below stones and boulders there is a large and varied fauna of *Subninella undulata, Euchelus baccatus* (Menke), *Fasciolaria australasia* Perry, *Hipponyx foliacea* Quoy and Gaim, *Pyrene tayloriana* (Reeve), *Marginella pygmaea* Sowerby, *Alliodoris marmorata* Bergh, *Tethya diploderma* Schmidt, *Coscinasterias calamaria* (Gray), *Tosia australis* Gray and *Patiriella calcar* (Lam.). This latter species is very numerous in some places, numbering as many as 10 per square foot. The hermit crab, *Clibanarius strigimanus* (White) is found inhabiting *Fasciolaria* shells.

Also found below stones is the small Symbranchid fish *Alabes rufus* (Macleay). Several species of small fishes swim in the water at the edge of the weed, and seek shelter in the scrub. Most common are small specimens of *Cristiceps australis* Cuv. & Val. and two species of leather-jackets. Other species identified with certainty are *Physiculus barbatus* (Günther), *Pseudolabrus tetricus* (Richardson) and the flathead *Platycephalus bassensis* Cuv. and Val.

Transect 12

Station	At Honeymoon Bay, No. 3.
Date	February, 1950.
Type	Sheltered rocky coast.
Maximum wave exposure	s (1-8) 1. b. 3.
Description	The transect is on the rocks at the south end of Honeymoon Bay, No. 3. It is to seaward of several small isolated rocky outcrops in the sand. The slope is sun exposed.
Geology	Red granite.
Tidal data	Approximately similar to those for Hobart.
Physical environment	As above.
Zonation	As in Transect 10.

It is not intended to describe fully the details of zonation as seen on this transect. The main features of the zonation are the same as those seen at Coles Bay and the fauna of the shore above the barnacle zone is identical to the Coles Bay section.

The mussel *Brachyodontes rostratus* forms a band just above the lower limit of the barnacle belt. It lives in cracks with the chiton *Sypharochiton pellis-serpentis*. At the same level only one individual of the barnacle *Catophragmus polymerus* was noted.

The *Galeolaria* belt is not as fully developed here as at Coles Bay. It is very narrow (about two inches in vertical height) and the tubes are scattered thinly on the rocks. At one place on the shore there is a mass of tubes up to four inches in thickness. From the presence of this mass it is probable that most of the *Galeolaria* belt was covered by thick aggregations of worm tubes, but at some recent time these colonies have been killed or broken. It may be noted here that a similar state of affairs has been observed at Dodge's Ferry, Frederick Henry Bay. Here on December 5th, 1948, there were masses of *Galeolaria* tubes of considerable extent and up to four inches in thickness. These formed the habitat for numerous other species, notably *Lasaea australis* and *Ibla quadrivalvis* (Cuvier). In December, 1950, the rocks were nearly bare with only young worms living on them. In a few places the original masses were still intact. These latter must serve as a breeding stock for the repopulation of the area. The reason for this sudden change in numbers of the serpulids is not known. Returning to Honeymoon Bay, it is obvious therefore, that the *Galeolaria* belt is not in a fully populated state and that some change may be expected over the next few years.

Below the worms is a *Hormosira* belt which in turn is replaced by a *Corallina* belt. The latter extends as far as the Infralittoral fringe which is dominated by a *Cystophora* association similar to that at Coles Bay.

On the same slope of rock slightly to the west of the transect the *Hormosira* belt is replaced by an isolated patch of the mussel *Mytilus planulatus*. (Plate III.) A rock off-shore is populated by mussels alone, but over most of the shore near the transect *Hormosira* is dominant. There is some evidence of competition between the mussels and *Hormosira* on this transect and on the shore at the north of Honeymoon Bay, No. 3. (Plate III.) At two places in the latter area the mussel, also *Mytilus planulatus*, is dominant. Over the rest of the surface at the north end of the bay the two species are in severe competition for space, the alga being dominant. Similarly on this transect, the alga and the mussel are in competition for space.

On this transect one individual of the ascidian *Pyura praeputialis* (Heller) was found. On a rock lying within Honeymoon Bay No. 3 but below the tidal level occupied by *Cystophora*, numerous individuals of this species are crowded together.

On the sun sheltered faces the limpet *Cellana limbata* and the barnacles *Catophragmus polymerus* and *Tetraclita purpurascens* are found. The viviparous anemone *Actinia tenebrosa* (Farqu.) is found locally in cracks and other sun sheltered places. This species is synonymous with the British *A. equina* Linn. (Blackburn, 1937).

In all of the north part of Honeymoon Bay No. 3 the mussel *Brachyodontes rostratus* prefers level or near level surfaces.

Discussion

The salient feature of the intertidal region above the Infralittoral fringe, as at Blackman's Bay, is the poverty both in species and numbers of the fauna and flora. Due to the lack of time no density counts were undertaken, but the fauna of the Midlittoral, especially above the Patelloid belt, is noticeably poor.

As the general poverty of the upper intertidal belts is pronounced on both sides of the peninsula, it may not be attributed to exposure to wave action. It has been shown by Hatton and Fischer-Piette (1932) that barnacles prefer places where there is considerable wave action. At Sleepy Bay there is very strong wave action yet the barnacles are poorly developed both in numbers and size. On rocks with a southerly aspect there is a slight increase in the number of barnacles present but this is not compatible with the increase one might expect if sun exposure were the controlling factor. This latter feature has been noted in all localities visited to date but in all other areas the population of barnacles on sun sheltered faces of rocks is very much greater than on the exposed faces and this suggests that the sun is the controlling factor. The sun exposure on the Freycinet peninsula is more rigorous than at Blackmans Bay but this can hardly be accepted as a valid reason for the scarcity of numbers of some species of the barnacles as these species are also found on the New South Wales coast. On the latter coasts the sun is considerably stronger than any encountered in Tasmania. The percentage exposure to dessication which these barnacles suffer cannot be compared with that for barnacles at similar tidal levels on the Mainland as there are no exposure figures available for Australia. Also, in sun sheltered places there is no luxuriant growth of barnacles.

On the east coast which is exposed to the continual surge of the oceanic swell there is not always spray due to the deadening effect of the kelp on the waves. The wave action, except in gales, is more in the nature of a three feet to six feet rise and fall of sea level without heavy spray. This may be altered by the local topography, but in general on most of the shore there is no spray. Thus, in spite of being a coast exposed to severe wave action, the intertidal levels above the height reached by the waves at 'low low' water in the summer are exposed to the maximum action of dessication. This is, in effect, the explanation offered by Dakin, Bennett and Pope (1948) for the upper 'cut off' of the Infralittoral fringe. In a few places on the Tasman sea coast near Sleepy Bay there is spray all the time, but most of these are inaccessible. At the few places where the effects of this continual spray were examined there was the usual raising of faunistic levels on the shore but no outstanding increase in numbers of the barnacle population.

On the wave sheltered Oyster Bay side of the peninsula there is also a poor barnacle fauna. As on the ocean coast there is no great increase in the numbers of barnacles in sun sheltered places.

It is tentatively suggested that the red granite does not offer a suitable substratum for intertidal organisms in general and, in particular, barnacles. This suggestion may have to be modified as further work is undertaken.

The lichens of the Supralittoral zone show a different vertical distribution from that prevalent in the Blackman's Bay area. In Transect 10 the orange lichens are separated from the *Melaraphe* belt by a broad band of bare rock. This is also characteristic of the more exposed parts of Pierson's Point. In Transect 9, however, the lichens follow directly on the upper limit of the *Melaraphe* zone. In Transect 9 the *Melaraphe* and lichen belts are both closer to the sea than in Transect 10 and previous transects at Blackman's Bay. This may be correlated with a greater amount of spray at Sleepy Bay allowing an upward extension of the upper limit of the *Melaraphe* belt. This wider range results in the elimination of the band of bare rock between the two zones. At the Chateau (Transect 11) the restriction of spray causes the *Melaraphe* belt to be only four inches in vertical height. In this case the smooth rounded surface of the granite does not offer a very suitable habitat for the gastropods. At the Honeymoon Bay transect, where spray is greater during easterly weather than that at Coles Bay, the *Melaraphe* belt is one foot five inches in vertical height.

Table II shows the faunal levels of the different belts at the transects considered in this work.

Bembicium nanum (Lam.) and Trochids are absent from the Sleepy Bay area. Their absence from wave exposed transects has been noted previously (Guiler, 1950, p. 173).

The constitution of the Patelloid belt is the same in both of the major areas described to date. The numbers of the various species are different from at Blackman's Bay. In particular, we may note the *Siphonaria diemenensis* is dominant on the peninsula in place of *Patelloida alticostata* at Blackman's Bay. The population of the Patelloid belt on the east coast is greater than at Hobart.

The absence of *Galeolaria* on wave exposed rocks has already been suggested by the observations made at Transect 5 (on dolerite at Kingston). This result is fully substantiated here where the serpulid does not form a band on the Tasman Sea side of the peninsula. The space thus, theoretically, made available for colonization is largely occupied by an upward extension of the Patelloid belt and partly by a downward extension of the barnacles. Included in the upward movement of the Patelloid belt is a similar movement of other forms inhabiting the belt.

In Transect 10 there is a poor line of demarcation between the Patelloid and barnacle belts. This may be due to the wave action varying considerably over short periods of time. This in turn would allow the larvae of forms from both belts to fix themselves in the mixed belt. If the wave action were constant in intensity a sharper line of demarkation would have been noticed.

In the Coles Bay area, *Brachyodontes rostratus* forms a strip within the barnacle belt. The species is found on wave exposed coasts but it is not plentiful. At Blackman's Bay, the mussel usually occurs in the Patelloid belt. (Table III.)

The mussel *Mytilus planulatus*, which forms extensive beds on semi-exposed coasts in the Blackman's Bay area, is virtually absent from the Sleepy Bay region. There are a few small specimens found in clefts as noted above but neither this species nor any other mussel species forms the dense beds seen at other places in Tasmania. The distribution of this species is also controlled in part by wave exposure as has been discussed in the first paper of this series.

On the wave exposed coast the calcareous algae are more fully developed than seen hitherto. In particular, we might note the large coral-like masses of the alga shown in Plate 5. This alga, which I have not been able to have identified, is a very noticeable feature of the lower shore regions. As noted above, it forms an important habitat in the *Coralline* belt. In the Blackman's Bay area the *Corallines* and *Lithothamnia* are not nearly so well developed.

The ascidian, *Pyura praeputialis*, occurs on the wave exposed coast in no greater numbers than in the Blackman's Bay area. It is found in small numbers in wave sheltered positions on the east side of the peninsula and in larger numbers at Honeymoon Bay. At no place on the peninsula is it as plentiful as at Dodge's Ferry or Pitt Water, both in Frederick Henry Bay, near Hobart.

The Infralittoral fringe shows the greatest difference in dominant types, not only between Sleepy Bay and Coles Bay but also between both these places and Blackman's Bay. At Blackman's Bay the larger algae are not found in quantity at the extreme limit of low water, but below this level plants occur in some numbers. The common species are *Macrocystis pyrifera*, *Xiphophora* and a few *Ecklonia radiata*. The Infralittoral fringe is occupied by a mixture of the larger forms.

At Sleepy Bay the very big alga *Sarcophycus potatorum* dominates the Infralittoral fringe almost to the exclusion of all other species. Also, there is a considerable difference in the density of *Coralline* colonization, with the best development seen on wave exposed coasts and the least at places where the dense *Cystophora* growths permit only a very small colonization by encrusting forms. Kitching (1937) notes that the slow growing *Corallina* at the Infralittoral fringe appears to be able to exclude the much larger *Himanthalia*. This condition, he also states, is probably reversed in deep water. If the *Cystophora* at Coles Bay is in a climax state, and there is little evidence for not making this assumption, there does not appear to be a similar action between the *Corallines* and *Cystophora* in this area. The narrow *Coralline* belt above the *Cystophora* may be the result of inter-specific action but there is no field or experimental evidence available upon which to base any deductions.

In numbers of both species and individuals the Infralittoral fringe at both the localities considered in this paper is less densely populated than at Blackman's Bay. This can be accounted for by the absence of mussel beds. These latter form a most suitable habitat for numerous intertidal species which have been described in the first paper of this series in terms of the epi-, endo- and hypobiose of Gislén (1930).

TABLE II

The relation of the intertidal belts at Transects 9 to 12, Freycinet Peninsula.

Transect 9 Lichens	Transect 10 Lichens Bare Rock	Transect 11 Bare Rock	Transect 12 Bare Rock
Melaraphe	*Melaraphe*	*Melaraphe*	*Melaraphe*
Barnacles	Barnacles with *Brachyodontes* and *Galeolaria* in cracks	Barnacles with *Brachyodontes* and *Austrocochlea* in cracks	Barnacles with *Austrocochlea*
	Catophragmus	*Brachyodontes* with *Sypharochiton* in cracks	*Brachyodontes*
Few *Galeolaria* with *Brachyodontes* in cracks		*Galeolaria*	*Galeolaria*
Patelloid	Patelloid	*Hormosira*	*Hormosira* and/or *Mytilus*
Corallina	*Corallina*	*Corallina*	*Corallina*
Sarcophycus	*Sarcophycus*	*Cystophora*	*Cystophora*

TABLE III

The zonation seen on the Freycinet Peninsula compared with that seen at Blackman's Bay. Transects 10-12 as in text, Transect 1 at Pinnacle Point, Blackman's Bay, Transect 2 at the north end of Blackman's Bay and Transect 5 on dolerite at Kingston.

Transect 10 Orange lichens Bare rock	Transect 11 Absent	Transect 12 Absent	Transect 1 Lichens Bare rock	Transect 2 Lichens Bare rock	Transect 5 Lichens Bare rock
Melaraphe	*Melaraphe*	*Melaraphe*	*Melaraphe*	*Melaraphe* with barnacles in cracks	*Melaraphe*
Barnacle with few *Gcleolaria* and *Brachyodontes* in cracks	Barnacles with *Brachyodontes* and *Austrocochlea*	Barnacles with *Brachyodontes* and *Austrocochlea*	*Bembicium* Barnacles	Barnacles with *Brachyodontes* in cracks	Barnacles
Catophragmus	Barnacles *Galeolaria*	Barnacles *Galeolaria*	*Galeolaria*	*Brachyodontes* with *Galeolaria*	Variable with wave action
Patelloid	*Hormosira*	*Hormosira* and/or *Mytilus*	Patelloid *Brachyodontes* Patelloid *Catophragmus*	*Catophragmus*	*Catophragmus*
Corallina	*Corallina*	*Corallina*	*Mytilus*	*Mytilus*	*Mytilus*
Sarcophycus	*Cystophora*	*Cystophora*	*Laurencia* *Macrocystis*	*Laurencia*	*Laurencia*

Under rocks, in clefts and other sheltered places both at Blackman's Bay and the Freycinet Peninsula there exists a varied and numerous fauna. Most of this fauna is difficult to identify, being composed mainly of those groups of animals and plants which have never been fully studied in Tasmania. Some of these species have been noted but at present it is intended to name the more obvious and ecologically important of the intertidal species. On exposed coasts the fauna and flora is in the nature of a hypobiose rather than the epibiose of sheltered coasts.

I do not yet propose fully to compare the intertidal region of Tasmania with that of other places in Australia. A few brief notes of comparison between Tasmania and New South Wales will suffice until such time as the work is more complete and other areas in Tasmania have been studied. A general comparison of the Australian intertidal zones as proposed by various authors has been given in the description of the Blackman's Bay area.

The intertidal ecology of New South Wales has been described by Hedley (1915), Fischer (1940b), Pope (1943) and Dakin, Bennett and Pope (1948). Fischer (1940b) gives a few brief notes comparing the zonation in New South Wales with that in Tasmania (p. 307). He based his description on a few brief visits to the shore at Burnie, in the Bass Straits area, and Hobart. A wave exposed coast was not examined. However, the comparative value of the work is not diminished as the sheltered coasts of N.S.W. are also considered.

Fischer states that the *Galeolaria* and *Melaraphe* zones in Tasmania are certainly comparable with the same zones as defined by Hedley at Sydney. The former zone at Sydney forms a belt 18 inches to two feet in width and up to eight inches in thickness (Dakin, et al., 1948). The greater width of the belt at Sydney compared with Hobart is due to the larger tidal range. Both Hedley and Fischer state that the species occurs on wave and surf swept headlands and Dakin and others note that the species extends through all degrees of exposure to the calm waters of Sydney Harbour. Fischer recorded *Galeolaria* as rare in calm waters. Pope (1943) notes that *Galeolaria* does not form a complete covering for the rocks at Long Reef. Comparing this with Tasmania we find that the tubes are rare on coasts which are fully exposed to wave action. This is similar to the New South Wales condition since Dakin, Bennett and Pope note that the species does not flourish where wave action is intense. From the descriptions of *Galeolaria* in New South Wales I think that the species in Tasmania has less toleration for wave action as even the turbulence at Transect 5 is sufficient to cause diminution in numbers. The formation of thick crusts of worm tubes at Sydney seems to reach a higher degree of development than any yet seen in Tasmania where a 4-inch crust is about the maximum thickness observed. In conclusion, this species in Tasmania is not as robust as in New South Wales, requiring less wave action for successful growth. It also flourishes in wave sheltered situations but does not form a thick incrustations on rocks in Tasmania.

The ascidian, *Pyura praeputialis*, is present on wave exposed coasts in New South Wales. Hedley (1915) notes that it demands rough seas, Fischer describes it as living on 'points battus'. Dakin, Bennett and Pope are more specific and have decided that the species requires ocean water with considerable but not excessive wave action. The species is also found in estuaries and land locked bays but is best developed opposite the seawards aperture of the bay (Dakin et al., 1948, p. 205). In Tasmania, the species occurs very infrequently on wave exposed coasts. At Blackman's Bay there is about one individual to every 50 feet of coast. On the east coast at Sleepy Bay individuals of this species are more numerous

but do not form clumps. The species at the latter area requires searching for before it can be located. In wave sheltered places in Tasmania the species is frequently very common, occurring in dense sheets on rocks. Some of these localities are to be described in future work. The species does not seem to have a preference for ocean waters. Tentatively, it may be said to prefer estuarine or enclosed waters.

On semi-exposed Tasmanian coasts the mussel *Mytilus planulatus* forms widespread beds. This feature is absent from wave exposed coasts. Similar beds do not form an important part of the shore fauna at Sydney (Hedley, 1915). Fischer (loc. cit.) records *M. planulatus* as occurring in Sydney in calm waters. Dakin, Bennett and Pope record the presence of *Mytilus obscurus* Dunk. but do not mention any formation of mussel beds. We may assume that mussel beds on semi-exposed coasts is a feature of Tasmania which is not shared with New South Wales.

Dakin, Bennett and Pope record the mussel *Brachyodontes rostratus* as forming sheets on parts of the Victorian coast. In the parts of Tasmania examined, the species occurs in clefts in rocks in a similar manner to that noted by the same authors for the same species in New South Wales.

The algae of the Infralittoral fringe are different from those found over most of the coast of New South Wales. *Ecklonia radiata* (Turn.) J. Ag. and *Phyllospora comosa* (Labill.) Ag. are the dominant species over the greater part of the coast of the latter state. *Sarcophycus potatorum*, highly developed on the Tasmanian coasts, appears at the south end of the New South Wales coast. *Ecklonia* has been found at Blackman's Bay but is not common. Very often, *Macrocystis* is a feature of semi-exposed and fully exposed coasts in Tasmania.

I do not propose at this stage to compare the features of the Tasmanian intertidal region with those described in South Africa by the team of workers collaborating with Prof. T. A. Stephenson. A few interesting points are noted below.

There exists a similarity in the zones described on the east coast of Tasmania and the west coast of South Africa (Bright, 1938a & b; Stephenson, Stephenson & Day, 1940). In South Africa the mussels, *Mytilus crenatus*, may replace limpets where the wave action is intense, but in Tasmania the opposite is the case. There are no *Pyura* beds in either locality. The large Infralittoral algae are cold water species in both countries. There is a Patelloid belt in both areas though this may be modified in South Africa.

In conclusion, it is suggested that the intertidal fauna and flora of wave exposed coasts in South and East Tasmania show greater ecological affinities with South Africa than New South Wales.

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FIG. 1.—The Infralittoral fringe at Sleepy Bay. The photograph also shows the barenes of the Midlittoral.

FIG. 2.—Close up view of Infralittoral fringe at Sleepy Bay. The prominent piece of *Sarcophycus* was 2½ inches across.

FIG. 1.—The junction of the *Patelloid* and *Corallina* zones at Sleepy Bay. The large chiton is *Plaxiphora albida* and is 4 inches in length. The large domes are encrusting forms of the coral-alga. *Corallina* is out of focus at the bottom right of the figure.

FIG. 2.—Small island off-shore at Sleepy Bay. The cleft is populated by *Sarcophycus*.

Fig. 1.—Shore at the southern end of Honeymoon Beach No. 3 showing mussels and *Hormosira*.

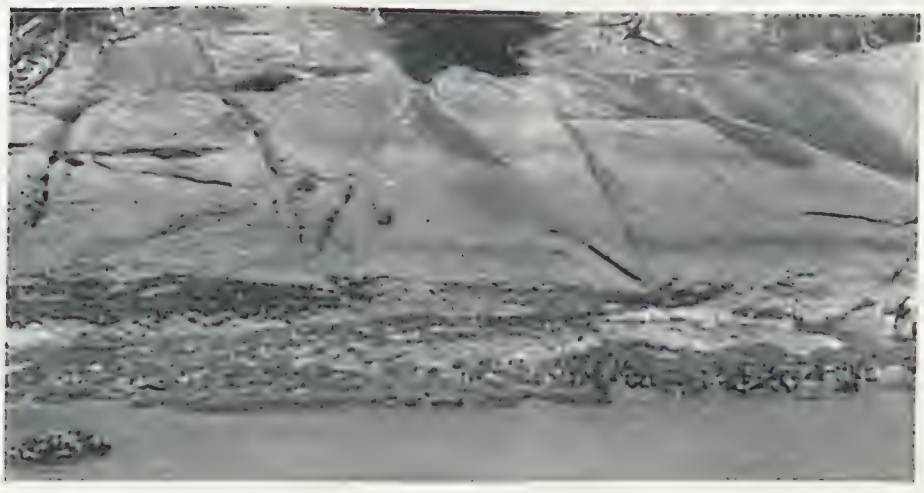

Fig. 2.—Shore at the northern end of Honeymoon Beach No. 2 showing inter-specific competition between *Mytilus* and *Hormosira*.

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Observations on the Surface Structure of the Hairs of Tasmanian Monotremes and Marsupials

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WITH 108 TEXT FIGURES

Summary

In this paper brief observations are made on the principal dimensions, cross-sectional shapes and cuticular scale patterns of hairs of the Tasmanian monotremes and marsupials.

The observations on the cuticular scale patterns alone, without considering other elements of the hair shaft, are of only limited value in a comparative study of marsupial hairs. However, it is suggested that a detailed microscopic examination of these hairs would probably prove to be of taxonomic value.

The marked changes in scale form, which are usually found along a single hair, are considered to be of an inherent and genetic character and are not caused by varying amounts of attrition or by dehydration of the hair shaft.

The cross-sectional shape, although not always constant, is found to be a useful character in the identification of Tasmanian monotreme and marsupial hairs. The unique structure of the protective hairs of *Isoodon* and *Perameles* is indicated.

Introduction

The present paper deals very briefly with the surface structure of a small sample of mid-dorsal body hairs taken from at least one representative of each of the Tasmanian monotremes and marsupials. The details of the specimens are set out in Table I, and the principal dimensions of the hairs examined are recorded in Tables II and III.

The principal object of this investigation is to draw attention to the probable taxonomic value of the arrangement of the cuticular scales in marsupial hairs. At the beginning it was hoped to be able to build a simple key to the characteristics. This could most probably be achieved in a more detailed examination.

Although numerous studies have been made of the mammalian coat, only a few workers have made any detailed study of the surface structure of hair. Both the type of hair and the general colour of the coat are important external characters and they are used extensively for taxonomic purposes. However, the microscopic structure of hair from this point of view has been largely neglected.

Hausman (1920*a*, 1920*b*, 1920*c*, 1930), Brown (1942) and others have emphasized the importance of the scale patterns on hairs. Hausman (1930) has shown that the cuticular scale types are directly related to the diameter of the hair shaft. In a study of the head hair of humans Wynkoop (1929) has shown that age has little or no bearing on the microscopic appearance of the cuticular scales. Brown (1942) considers that little additional information is gained from a microscopic examination of hair gathered from different regions of the human body.

The present contribution does not attempt to add anything new to the papers by Hausman (1920*a*) and Wildman and Manby (1938) on the hair structure of the monotremes. The notes on this group are included for comparison with those on the Tasmanian marsupials.

The scarcity of publications on the scale pattern arrangement in marsupial hairs suggests that it is worth recording these short preliminary observations.

The taxonomic nomenclature used is that of Iredale and Troughton's check-list (1934).

TABLE I

List of Specimens

Species	Animal No.	Source	Sex	Age
Ornithorhynchus anatinus	1	Central Tasmania. August, 1950	?	Adult
Tachyglossus setosus	1	Lake Leake, Tasmania. August, 1949	♂	Adult
Antechinus swainsonii	1	Sandy Bay, Tasmania. July 25, 1950	♂	Adult
Antechinus minimus	2	Queen Victoria Museum, Launceston, Tasmania	♂	Adults
Sminthopsis leucopus	1	National Museum, Melbourne	?	Adult ?
Dasyurus quoll	1	Sandy Bay, Tasmania. September, 1950	♀	Adult
Dasyurops maculatas	1	Zoology Department, University of Tasmania	♀	Adult
Sarcophilus harrisii	1	Queenstown, Tasmania, June 16, 1949	♂	Adult
	1	Ellendale, Tasmania. August 29, 1949	♂	Juvenile
Thylacinus cynocephalus	1	Queen Victoria Museum, Launceston, Tasmania	?	Adult
	1	Queen Victoria Museum, Launceston, Tasmania	?	Juvenile
Isoodon obesulus	1	Lindisfarne, Tasmania. July 10, 1950	♂	Adult
Perameles gunnii	1	Rifle Range, Hobart, Tasmania. June 6, 1950	♀	Adult
Cercartetus nanus	1	National Museum, Melbourne	?	?
	1	Tasmanian Museum, Hobart, Tasmania	?	Adult
Eudromicia lepida	1	Zoology Department, University of Tasmania	♀	Adult
Petaurus breviceps	1	Miena, Central Tasmania, August, 1949	♂	Adult
Pseudocheirus convolutor	2	Ulverstone, Tasmania. July 15, 1950	♂ and ♀	Adults
Trichosurus vulpecula	1	Branxholm, Tasmania. June, 1950	♀	Adult
Vombatus ursinus	1	Southern Tasmania. October, 1950	♂	Adult
Bettongia cuniculus	1	Taranna, Tasman Peninsula, Tasmania. March 18, 1950	♀	Adult
Potorous tridactylus	1	Rifle Range, Hobart, Tasmania. July, 3, 1950	♀	Adult
Thylogale billardierii	1	Miena, Central Tasmania. July 17, 1950	♀	Adult
Wallabia rufogrisea	2	Branxholm, Tasmania. June and August, 1950	♂ and ♀	Adults
Macropus tasmaniensis	1	Gladstone, Tasmania. July, 1950	♀	Adult

TABLE II

Principal Dimensions of Protective Hairs from Adult Specimens

Species	Approx. Length in mm.	Diameter or greatest wdith in microns.			
		Base	Widest region.		
			Min.	Mean	Max.
Ornithorhynchus anatinus	15	60-66	185	200	215
Tachyglossus setosus *	25	95-120	200	253	350
Antechinus swainsonii	17	12-18	45	62	75
Antechinus minimus	17	9-18	25	38	50
Sminthopsis leucopus	15	7-9	24	32	45
Dasyurus quoll	27	20-27	35	64	85
Dasyurops maculatus	25	18-34	40	78	105
Sarcophilus harrisii	32	30-65	70	100	120
Thylacinus cynocephalus *	16	25-35	45	62	78
Isoodon obesulus	22	25-40	200	249	295
Perameles gunnii	21	17-25	90	124	155
Cercartetus nanus **	8	7-9	13	20	26
Eudromicia lepida **	10	6-14	12	20	34
Petaurus breviceps **	15	8-13	12	17	28
Pseudocheirus convolutor	31	20-25	34	49	63
Trichosurus vulpecula	60	20-30	55	73	92
Vombatus ursinus **	38	90-150	130	190	240
Bettongia cuniculus	31	17-24	35	58	78
Potorous tridactylus	40	12-22	29	68	95
Thylogale billardierii	58	17-25	43	54	82
Wallabia rufogrisea	57	25-38	45	71	90
Macropus tasmaniensis *	42	19-27	25	52	75

* The dimensions given here are of the straight hairs.

** The dimensions of all the hairs examined are recorded above.

TABLE III

Principal Dimensions of Fur Hairs from Adult Specimens

Species	Approx. Length in mm.	Diameter or greatest wdith in microns.			
		Base	Widest region.		
			Min.	Mean	Max.
Ornithorhynchus anatinus	10	8-9	12	14	20
Tachyglossus setosus *	20	25-38	50	72	85
Antechinus swainsonii	12	7-9	16	18	22
Antechinus minimus	10	6-8	12	17	20
Sminthopsis leucopus	11	6-7	10	11	13
Dasyurus quoll	18	15-18	15	19	25
Dasyurops maculatus	18	9-12	12	22	30
Sarcophilus harrisii	26	18-30	25	48	65
Thylacinus cynocephalus *	14	12-20	20	32	40
Isoodon obesulus	12	6-9	18	24	34
Perameles gunnii	15	7-11	13	20	22
Cercartetus nanus **	....	....	....	....	....
Eudromicia lepida **	....	....	....	....	....
Petaurus breviceps **	....	....	....	....	....
Pseudocheirus convolutor	22	8-20	13	25	30
Trichosurus vulpecula	37	8-20	15	32	40
Vombatus ursinus **	....	....	....	....	....
Bettongia cuniculus	20	11-14	19	22	30
Potorous tridactylus	25	12-15	20	25	35
Thylogale billardierii	37	8-13	13	22	30
Wallabia rufogrisea	40	15-30	20	31	40
Macropus tasmaniensis *	35	15-18	19	27	30

* The dimensions given here are of the wavy hairs. ** See Table II.

Methods

I. The methods employed for the examination of the surface structure of hairs are simple and the materials needed are easily obtainable.

First Method

Dry Mounting. The hair specimens are washed in alcohol-ether and mounted dry. Small strips of gummed paper are used for fastening the cover-glass on to the slide. These dry preparations are used for making observations on the general shape of the longitudinal section, for making measurements of the diameter of the hair shaft and, where suitable, for checking the contour of the scales and obtaining the scale indices. Transmitted light will sometimes detail the scales but it is usually found necessary to use a beam of light from one side and just above the horizontal.

Second Method

Negative Impressions. The method described by Bachrach (1946) is satisfactory for revealing the surface structure of hair. With slight modifications this method is used for making most of these observations. Photographic plates ($3\frac{1}{2} \times 2\frac{1}{2}$ Process Plates are recommended as they may be handled under an OA safelight and are a convenient size for manipulation on the microscope stage) are washed in running water to remove backing. Fix plates in plain hypo solution and wash for 45 minutes. Place in "Photo-Flo" solution for five minutes to reduce the surface tension and thus assist even drying. Wipe off surplus water with a viscose sponge. Place in a glass jar to dry and cover to exclude dust. When the emulsion is quite dry to a depth of from 1-2 mm. from the edges, place the plates emulsion side up upon a level surface. The hair specimens are now carefully laid upon the still damp centres of the plates; if possible with all the tips facing the same direction. The plates are now covered with a piece of "Kodatrace" or thick cellophane to prevent the specimens from being crushed when weight is applied to them. The "Kodatrace" may be electrically charged in which case the hairs will be attracted to it thus upsetting any pre-determined arrangement. This charge may usually be removed by breathing upon the "Kodatrace". On top of the "Kodatrace" is placed a sheet of thick glass to protect it from uneven pressure. On the sheet of glass are placed books or other heavy objects in which the weight is evenly distributed. Twelve to fifteen pounds of weight is found most satisfactory. The specimens are left under the weight for about 30 minutes; the weights, glass and "Kodatrace" are then removed, and the photographic plates are replaced on edge in a glass jar, covered to exclude dust, and left to thoroughly dry. The hair specimens are then removed with a soft camel hair brush. The hair impressions are now ready for examination under the microscope. No cover-glasses are used as a mounting medium would fill up the specimen-moulds and thus lower their visibility. The impressions obtained by this method, when viewed directly, are negatives of the scale structure.

All the line drawings in this paper are made from photomicrographs of negative impressions obtained by the above method and all text figures are × 195.

Third Method

Positive Impressions. Koonz and Strandine (1945) describe a simple method for revealing the surface structure of hair. This method is rapid and gives good results when examining fine hairs but it is of little value when studying coarse hairs. A thin film of glycerin is placed on a clean large cover-glass. The hair specimens are then placed on the cover-glass and covered with several drops of

water soluble nigrosin solution. The excess fluid is removed by tilting or by placing blotting paper at the edge of the cover-glass. The nigrosin is then dried over a low flame or other heating unit. The hair specimens are removed from the dry nigrosin film and the cover-glass is inverted and placed on a microscope slide. The hair impressions are now ready for examination under the microscope. Using this method positive impressions are readily obtained.

II. Two methods are used for the examination of the cross-sectional shapes of hair specimens.

First Method

Examination of Cut Ends. A tuft of hairs is held tightly with a small piece of split carrot or potato and cut transversely, in the desired region, with a sharp blade razor. The piece of carrot or potato containing the cut hairs is then transferred to a microscope slide. Using reflected light useful information regarding the cross-sectional shape may often be obtained by this quick method.

Second Method

Embedding in Celloidin and Paraffin. It is sometimes, though fortunately not frequently, found necessary to prepare transverse sections of the hair shafts to determine their contours. The usual process of embedding in celloidin, impregnating with benzol and infiltration with paraffin is used. Staining is not necessary for obtaining the cross-sectional shape.

All the measurements of diameter or greatest width are obtained by using an ocular micrometer.

The Types of Mammalian Hair

In general, all hair can be divided into two types; the protective or guard hair, and the underfur or fur hair. The protective hair is usually long, coarse and straight; whereas the fur hair is usually shorter, fine and woolly. These two types of hair may be quite obvious but sometimes they are difficult to detect, and occasionally there is no definite line of demarcation between them.

The Structure of Hair

The structure of the hair shaft may vary in different animals but, in general, it is composed of an outer sheath of relatively structureless imbricate horny scales, called cuticle. Below the cuticle is the more solid part or cortex. In addition to these two layers, many types of hair also contain a central medulla filled with air cells.

In cross-section hairs present a variety of forms from circles to strongly flattened ovals, or they may be triangular, polygonal, dumb-bell-shaped or kidney-shaped. The shape of the cross-section, although not always constant, is found to be most useful and will sometimes eliminate many genera. The two Tasmanian members of the Peramelidae; *Isoodon* and *Perameles*, may each be identified from the cross-sectional shape of the broadest part of a single protective hair. In this family the transverse sections of the protective hairs will probably prove to be of important taxonomic value. The cross-sectional shape of a single hair shaft is usually constant but it may be variable throughout its length. The majority

of hair shafts show some variation in diameter throughout their length. The base is usually of less diameter than the mid-region. In most of the Tasmanian marsupials the protective hairs are widest distal of the mid-region and the tip usually tapers off to practically nothing.

For the identification of hair; the general colour, the shape of the longitudinal section, the shape of the cross-section, the scale pattern of the cuticle, the pigment contained in the cortical area and the structure of the medulla are all helpful guides.

The nomenclature used for the various kinds of cuticular scales was formulated by Hausman (1920*b*). This classification of scale types is used throughout this paper. The ratio of the length of the free proximo-distal portion of the cuticular scale (F) and the diameter of the hair shaft (D) is called the scale index (S.I.), F/D = S.I. The scale index usually varies inversely with the diameter. Because of this, scale indices may be applied only when hairs of similar diameter are being compared. In most of the Tasmanian marsupials the scale indices are so variable that they will not be included here, and it is doubtful whether they will prove to be of taxonomic value. In his paper devoted to the hairs of the North American Carnivora, Brown (1942, p. 252) remarks on the variability of their scale indices.

The cuticular scales on mammalian hairs fall readily into two types; the imbricate and the coronal. Imbricate scales are the most common type, whereas coronal scales are characteristic of the Chiroptera. In the Tasmanian marsupials coronal scales are sometimes found on the thinnest hairs and at the tips of the larger hairs.

A variety of scale forms is often found in a single hair. Hardy and Plitt (1940, p. 5) consider that, for practical purposes, four regions of the hair shaft may be considered as bearing characteristic scales. These regions are: 1. the base or proximal end; 2. the part adjacent to it; 3. the widest part of the shaft; and 4. the tip or distal end. Although hair specimens from different species may exhibit similar characteristics in one position, yet when all four regions are considered, differences can often be detected. In a detailed examination, it is necessary to consider the structural characteristics throughout the entire length of the hair shaft.

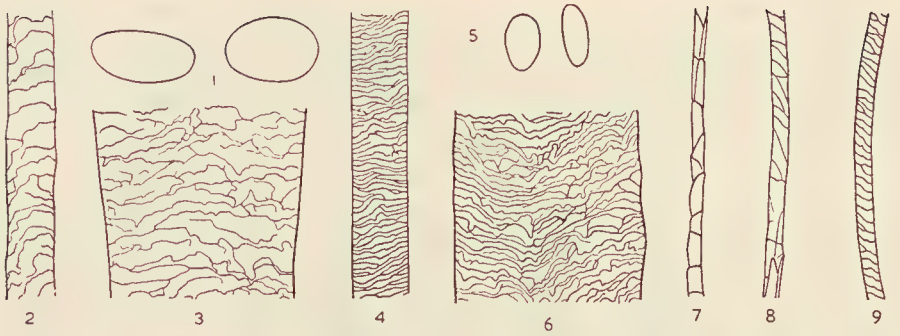
Monotremata

(FIGS. 1-9)

Hausman (1920*a*, p. 484) considers that the type of hair characteristic of the Monotremata is the flattened type represented by the protective hairs of *Ornithorhynchus*, and by the flattened and wavy hairs of *Tachyglossus*.

The presence of two distinct types of hairs in *Ornithorhynchus* will separate hair specimens of this animal from those of *Tachyglossus* in which there is no definite line of demarcation between the hair types.

The cuticular scales of the straight and wavy hairs of *Tachyglossus*, and the shields of the protective hairs of *Ornithorhynchus* are mostly of the flattened, crenate or irregular-margined type. The fur hairs of *Ornithorhynchus* are fine, circular in cross-section, and possess several types of cuticular scales. These scales are usually elongate to acuminate in the basal region and flattened in the distal region.



FIGS. 1-4 *Tachyglossus setosus* × 100.

Fig. 1. Wavy hair; transverse sections of mid-shaft.

Fig. 2. Wavy hair; basal.

Fig. 3. Straight hair; mid-shaft.

Fig. 4. Straight hair; distal.

FIGS. 5-9 *Ornithorhynchus anatinus* × 100.

Fig. 5. Protective hairs; transverse sections of distal region.

Fig. 6. Protective hair; widest region.

Fig. 7. Fur hair; basal.

Fig. 8. Fur hair; mid-shaft.

Fig. 9. Fur hair; distal.

Marsupialia

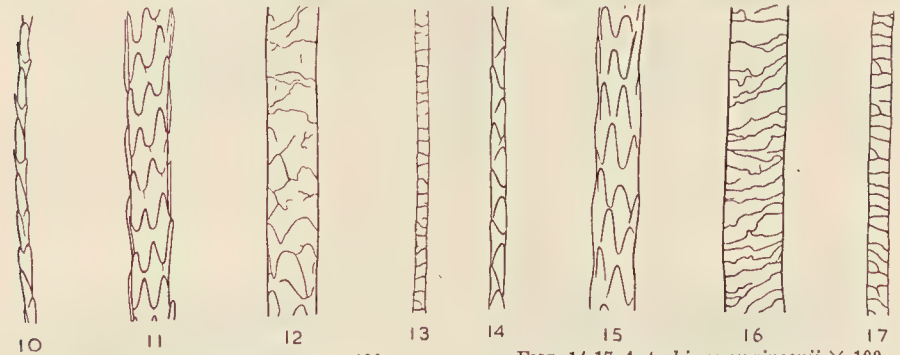
Suborder *POLYPROTODONTIA*

Family DASYURIDAE

(FIGS. 10-46)

The type of hair characteristic of most of the Dasyuridae is circular in cross-section. In all the Tasmanian representatives of this family, except *Thylacinus*, the coat is composed of two distinct types of hair.

At the extreme base of the protective hairs the cuticular scales are often flattened. This character is most noticeable in *Dasyurops* and *Sarcophilus*. Prominent elongated scales with smooth margins are the predominant type along the basal half of the protective hair shaft. As the full width of the hair is approached these elongated scales change form to a flattened, usually irregular-margined type. At the tip of the hair the scales may be of a simple coronal type.



FIGS. 10-13 *Antechinus minimus* × 100.

Fig. 10. Fur hair; basal.

Fig. 11. Protective hair; basal.

Fig. 12. Protective hair; distal.

Fig. 13. Fur hair; distal.

FIGS. 14-17 *Antechinus swainsonii* × 100.

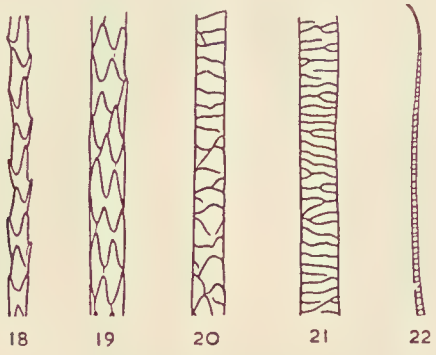
Fig. 14. Fur hair; basal.

Fig. 15. Protective hair; basal.

Fig. 16. Protective hair; distal.

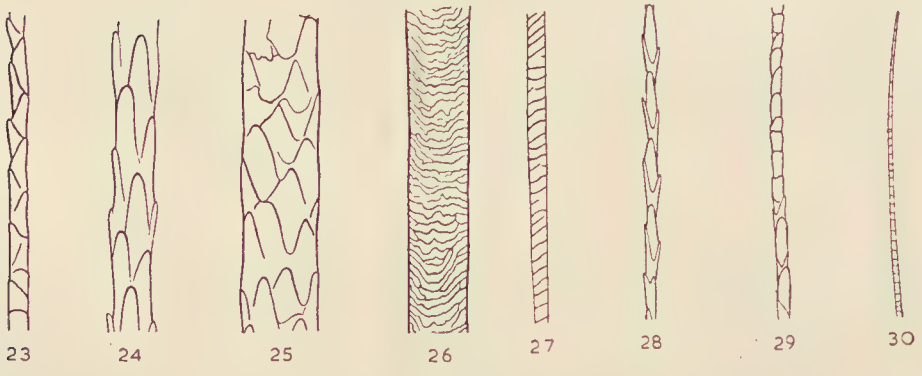
Fig. 17. Fur hair; distal.

There is sometimes an amazing variety of scale forms along a single fur hair. At the extreme base the cuticular scales are usually closely adpressed to the hair shaft and they appear flattened. This short region of flattened scales is often followed by alternate regions of elongate and flattened scales. At the tip simple coronal scales are often present.



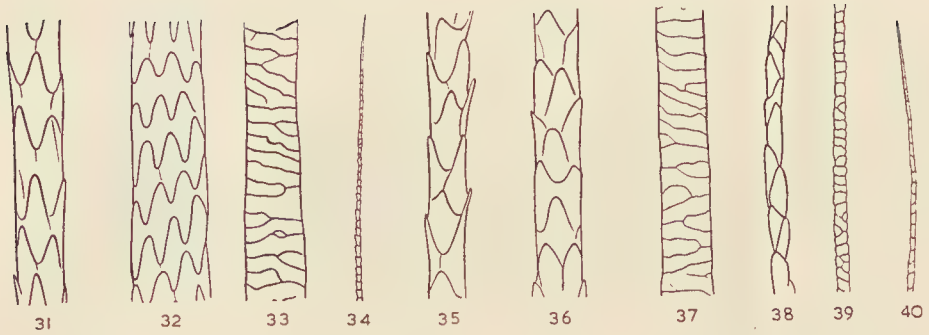
Sminthopsis leucopus × 100.

Fig. 18. Protective hair; basal.
Fig. 19. Protective hair; basal.
Fig. 20. Protective hair; distal
Fig. 21. Protective hair; distal.
Fig. 22. Protective hair; tip.



Dasyurus quoll × 100.

Fig. 23. Protective hair; basal.
Fig. 24. Protective hair; basal.
Fig. 25. Protective hair; mid-shaft.
Fig. 26. Protective hair; distal.
Fig. 27. Fur hair; base.
Fig. 28. Fur hair; basal.
Fig. 29. Fur hair; distal.
Fig. 30. Fur hair; tip.

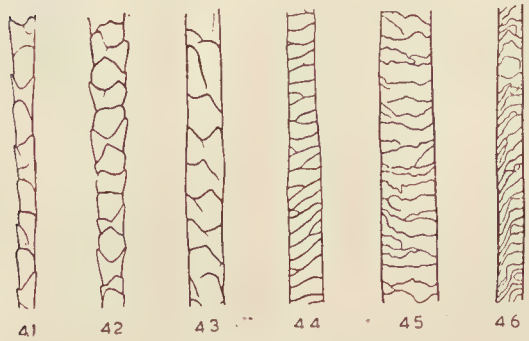


FIGS. 31-34 *Dasyurops maculatus* × 100.

Fig. 31. Protective hair; basal.
Fig. 32. Protective hair; mid-shaft.
Fig. 33. Protective hair; distal.
Fig. 34. Protective hair; tip.

FIGS. 35-40 *Sarcophilus harrisii* × 100.

Fig. 35. Fur hair; mid-shaft.
Fig. 36. Fur hair; mid-shaft.
Fig. 37. Protective hair; basal.
Fig. 38. Fur hair; basal.
Fig. 39. Fur hair; distal.
Fig. 40. Fur hair; tip.



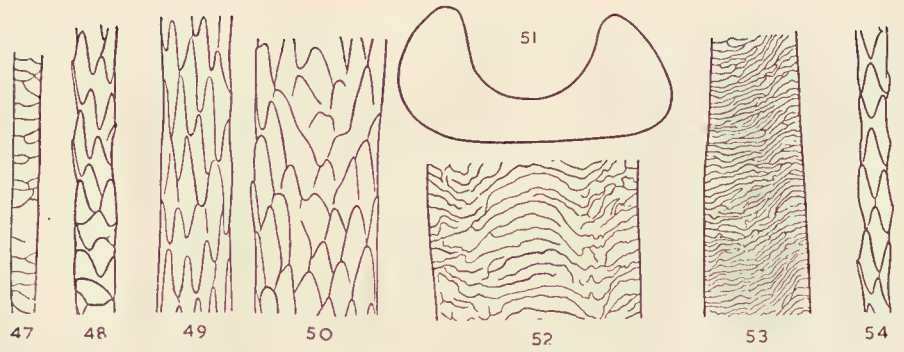
Thylacinus cynocephalus × 100.

Fig. 41. Wavy hair; basal.
Fig. 42. Wavy hair; basal.
Fig. 43. Wavy hair; mid-shaft.
Fig. 44. Wavy hair; distal.
Fig. 45. Straight hair; distal.
Fig. 46. Wavy hair; distal.

Family PERAMELIDAE

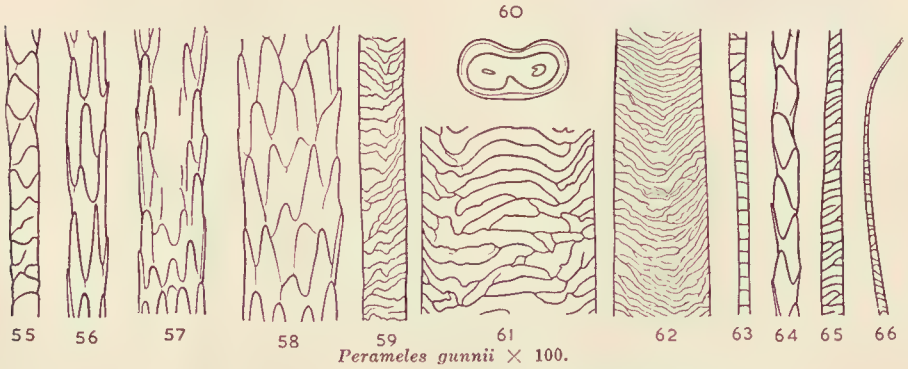
(FIGS. 47-66)

The two Tasmanian members of the Peramelidae may be recognized immediately by the characteristic shape of the protective hairs. In *Isoodon* the protective hairs are coarse, flattened and grooved on the anterior side along the greater part of the shaft (fig. 51). In most respects the hairs of *Perameles* are similar to those of *Isoodon* but there is a distinct difference in the cross-sectional shape (fig. 60). The fur hairs of both genera are fine and circular in cross-section.



Isoodon obesulus × 100.

Fig. 47. Protective hair; base.
Fig. 48. Protective hair; basal.
Fig. 49. Protective hair; basal.
Fig. 50. Protective hair; mid-shaft.
Fig. 51. Protective hair; transverse section of mid-shaft.
Fig. 52. Protective hair; distal.
Fig. 53. Protective hair; distal.
Fig. 54. Fur hair; basal.



Perameles gunnii × 100.

Fig. 55. Protective hair; base.
Fig. 56. Protective hair; basal.
Fig. 57. Protective hair; basal, beginning of groove.
Fig. 58. Protective hair; mid-shaft.
Fig. 59. Protective hair; distal.
Fig. 60. Protective hair; transverse section of mid-shaft.
Fig. 61. Protective hair; mid-shaft.
Fig. 62. Protective hair; distal.
Fig. 63. Fur hair; base.
Fig. 64. Fur hair; basal.
Fig. 65. Fur hair; mid-shaft.
Fig. 66. Fur hair; tip.

The cuticular scales of the protective hairs are flattened at the extreme base. This is followed by a short region of ovate scales and an extensive region of elongate, smooth-margined scales together with an increase in diameter and a flattening of the hair shaft. Near the basal end of the longitudinal groove the scales change form to a flattened irregular-margined type which is continued along the shaft to its distal extremity. Similar scales are found on both the concave and convex side of the hair shaft. The cuticular scales of the fur hairs are mostly elongated in the basal region and flattened in the distal region.

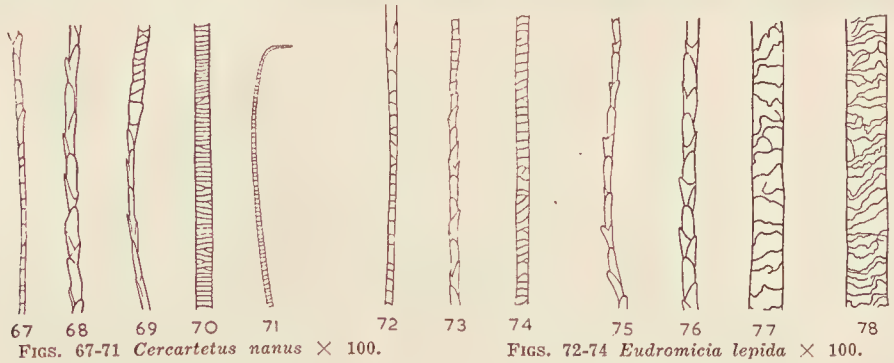
Suborder *DIPROTODONTIA*

Family PHALANGERIDAE

(FIGS. 67-84)

In *Cercartetus, Eudromicia* and *Petaurus* the coat is composed of fine soft hairs which are circular in cross-section. In *Pseudocheirus* and *Trichosurus* there are two distinct types of hair and the transverse sections usually present a slightly flattened or ovoid appearance.

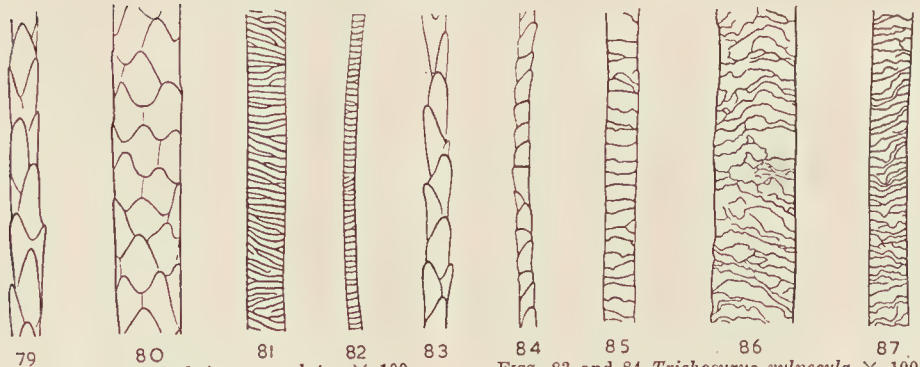
In the hairs of *Cercartetus* and *Eudromicia* the cuticular scales are similar. Alternate regions of elongate and flattened or simple coronal scales are usually present along a single hair shaft. In the basal region the scales are prominent and usually elongated with smooth margins. In the distal region simple coronal scales are the most common form encountered. In the hairs of *Petaurus* the cuticular scales of the distal region are often of a flattened irregular-margined type, but in other respects the hairs of this animal are similar to those of *Cercartetus* and *Eudromicia*. In *Pseudocheirus* and *Trichosurus* the cuticular scales of the protective hairs are flattened at the extreme base. This is usually followed by elongate scales in the basal region and flattened smooth-margined scales in the distal region. The scales of the fur hairs are elongated and prominent in the basal region; flattened or simple coronal in the distal region.



FIGS. 67-71 *Cercartetus nanus* × 100.
Fig. 67. Hair; base
Fig. 68. Hair; basal.
Fig. 69. Hair; mid-shaft.
Fig. 70. Hair; distal.
Fig. 71. Hair; tip.

FIGS. 72-74 *Eudromicia lepida* × 100.
Fig. 72. Hair; base.
Fig. 73. Hair; mid-shaft.
Fig. 74. Hair; distal.

FIGS. 75-78 *Petaurus breviceps* × 195.
Fig. 75. Hair; basal.
Fig. 76. Hair; basal.
Fig. 77. Hair; distal.
Fig. 78. Hair; distal



FIGS. 79-82 *Pseudocheirus convolutor* × 100.
Fig. 79. Protective hair; basal.
Fig. 80. Protective hair; mid-shaft.
Fig. 81. Protective hair; distal.
Fig. 82. Protective hair; distal.

FIGS. 83. and 84 *Trichosurus vulpecula* × 100.
Fig. 83. Fur hair; basal.
Fig. 84. Fur hair; distal.

FIGS. 85-87 *Vombatus ursinus* × 100.
Fig. 85. Hair; mid-shaft.
Fig. 86. Hair; mid-shaft.
Fig. 87. Hair; distal.

Family VOMBATIDAE

(FIGS. 85-87)

One representative of the Vombatidae is found in Tasmania. The coat is composed of fairly long and very coarse protective hair; fur hair almost or entirely absent. The hairs are oval in cross-section and the medulla is absent. These two characters alone will separate the hairs of *Vombatus* from those of the other Tasmanian Marsupials. The average size of the transverse section taken through the broadest part of the mature hair is 190μ × 125μ. The base of the hair usually measures from 90μ-150μ across.

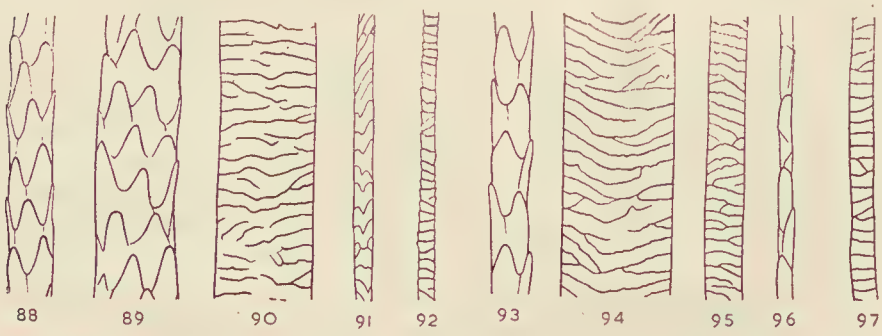
All the hairs show but one type of cuticular scale, the flattened irregular-margined type with almost no variation.

Family MACROPODIDAE

(FIGS. 88-108)

In *Bettongia, Potorous, Thylogale* and *Wallabia* the coat is composed of two types of hair. In *Macropus* the fur hair is almost or entirely lacking. In *Bettongia* and *Potorous* the transverse sections vary in contour from oval to an almost circular shape. In *Thylogale, Wallabia* and *Macropus* the contour of the transverse sections is for the most part elliptical. Glaister (1931, p. 83) examined cross-sections of "Wallaby" hair and remarks that "In several of the sections, however, a unilateral concavity is present which in certain instances is of a pronounced character and imparts to the sections a 'kidney' or 'bean' shaped appearance". This does indicate a slight resemblance between hairs of the Macropodidae and those of the Peramelidae.

In *Bettongia* and *Potorous* the protective hairs possess cuticular scales which are mostly elongated and protruding in the basal region and flattened in the distal region. At the tip of the hair the scales may be of a simple coronal type. In *Thylogale* and *Wallabia* the cuticular scales are usually elongated in the basal region and flattened or simple coronal elsewhere. In *Macropus* the scales are mostly of a simple coronal or flattened type with very little variation along the hair shaft.

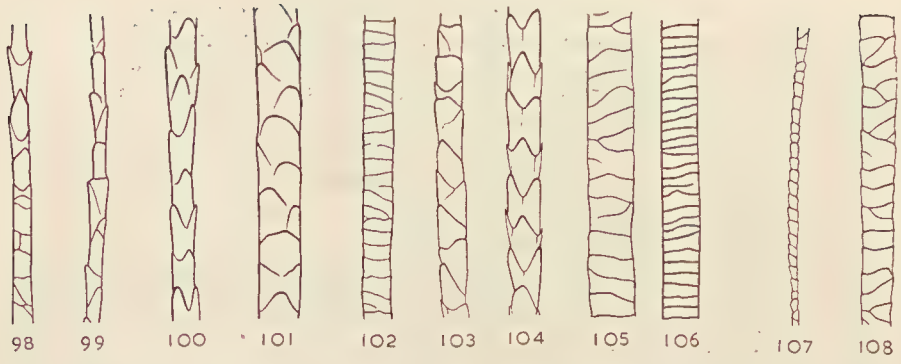


FIGS. 88-92 *Bettongia cuniculus* × 100.

Fig. 88. Protective hair; basal.
Fig. 89. Protective hair; mid-shaft.
Fig. 90. Protective hair; distal.
Fig. 91. Fur hair; mid-shaft.
Fig. 92. Fur hair; distal.

FIGS. 93-97 *Potorous tridactylus* × 100.

Fig. 93. Protective hair; basal.
Fig. 94. Protective hair; distal.
Fig. 95. Protective hair; distal.
Fig. 96. Fur hair; basal.
Fig. 97. Fur hair; distal.



FIGS. 98-102 *Thylogale billardierii* × 100.

Fig. 98. Fur hair; base
Fig. 99. Fur hair; basal.
Fig. 100. Fur hair; basal.
Fig. 101. Fur hair; mid-shaft.
Fig. 102. Fur hair; distal.

FIGS. 103-106 *Wallabia rufogrisea* × 100.

Fig. 103. Fur hair; basal.
Fig. 104. Fur hair; basal.
Fig. 105. Fur hair; mid-shaft.
Fig. 106. Fur hair; distal.

FIGS. 107 & 108 *Macropus tasmaniensis* × 100.

Fig. 107. Wavy hair; distal.
Fig. 108. Wavy hair; mid-shaft.

REMARKS

This paper does indicate the probable taxonomic value of a detailed microscopic examination of the hairs of the marsupials. However, the cuticular scales are often so much alike in the hairs of unrelated animals that a useful key for the accurate identification of hair, based on scales alone, would be of little value in a comparative study of mammalian hair.

Cuticular scales show some variation on contemporaneous hairs from a single specimen. Also, differences exist in scale form along the same hair, from base to tip. Some marsupials show this character much more strongly marked than others. An extreme instance of this change in structural character from the base to the tip of the hair, involving not only the cuticular scales but other elements of the hair shaft structure as well, is furnished by the protective hair of *Isoodon*.

Hausman (1930, p. 262) considers that the differences in scale form along a single hair "are the results of the differences in the activities of the cells of the hair papilla, plus also, it is believed, some differences in the gradual drying out of the hair shaft, plus also the effects of wear on the free ectal edges of the scales, particularly at the tip of the shaft. The activities of the papillal cells produce differences both at the tip and the base of the shaft, i.e., when these cells begin, and close, their mitosis. Along the middle of the shaft the scales are fairly uniform in shape and relationships".

The authors are of the opinion that neither dehydration nor attrition could cause the changes in scale form from the basal to the distal portions of a single hair. This is in close agreement with the findings of Wildman and Manby (1938, p. 343) in which they say that "A study of the scale-pattern along hairs, not only of the Monotremata but of other mammals, provides conclusive evidence that generally the changes in scale form from proximal to distal portions are innate and genetic in character, and are not caused by varying amounts of attrition".

The gross structure of many protective hairs, such as those of *Isoodon*, suggest that they have a limited growth period and are periodically shed.

In surface structure there does not seem to be any exact distinction between the hairs of the Polyprotodontia and those of the Diprotodontia. However, the cross-sectional shape is probably of more taxonomic value; but the character of the cuticle, cortex, and medulla, as revealed by transverse section, must be considered in a detailed microscopic examination of mammalian hair.

Minor differences between hair samples from different regions of the body of a single specimen will not be discussed here.

Insufficient material has been examined to discuss the intraspecific variation for any of the animals examined. Where hair samples from more than one specimen have been examined there is some variation in the surface structure but the sequence of scale forms along the hairs is usually the same.

The types of hair will not be discussed here. Hardy (1947, p. 145) draws attention to the need for examining the relation between the follicle types in the skin and the hair types in the pelage.

Acknowledgments

For assistance in obtaining many animals from which hair specimens have been taken especial thanks are due to Messrs. B. A. B. Edwards, E. R. Guiler, A. J. McIntosh, G. B. Sharman, and P. S. Young. Also, particular thanks are due to Professor V. V. Hickman for encouragement and advice, and to Mr. D. W. Peacock for the preparation of many photographs.

For hair samples of several animals (see Table I) we are indebted to the authorities of the Queen Victoria Museum, Launceston; the Tasmanian Museum, Hobart; and the National Museum, Melbourne.

The preliminary portion of this examination was carried out whilst one author was in receipt of a Research Grant from the University of Tasmania.

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On the Growths of Continents*

By

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With eight figures

Summary

A mechanism for the formation of arcs on the earth's surface is put forward. A physical cause for this process based upon the contraction hypothesis as stated by Jeffreys is stated and physical reasons given why the process should give rise to arcs. It is shown that the geology, the volcanism, the distribution of earthquakes and the whole pattern of existing active mountain ranges may be explained in terms of this process.

The question of how it has acted in the past and the causes of the changes in the pattern along which it is applied is discussed. So is the rate of volcanism.

The contributions of new and of secondary or eroded material to form continental shelves and the material for new marginal mountain ranges is estimated.

It is concluded that the proposed mechanism is physically valid and would serve to explain the growth during geological time of continents, oceans and atmosphere on a planet initially uniform and lacking these surface features.

Introduction

The physical characteristics of the earth may be described in several ways. The existing features may be defined; their history may be told; the processes which caused the earth to have a history may be discussed. A great deal is already known about the first two categories, the earth's features and the latter part of its geological history. Much less is known about the third, but it is with this search for a primary process which causes the earth to have internal motions, and to change its surface features that this paper is chiefly concerned. In this respect the earth is an engine. It does work to build mountains and cause earthquakes. Its horsepower has been estimated to be of the order of 10^{10} h.p.

For the purpose of the analysis to be made in this paper of the earth's internal processes three classes of information are available. They are observations made by the methods of field geology, analysis made by mathematical treatment based upon the fundamental laws of physics and observations made by physical, that is geophysical, methods. Assistance in the problem may also be obtained from the fields of geochemistry, geodesy and cosmology.

The methods of field geology have been adequate in order to describe the earth's surface as it is and to tell a great deal about its history, but they have not disclosed the cause of the earth's internal movements and there is no indication that they are likely to do so. In order to discover the processes that have given the earth a history, a consideration of physical laws is necessary, for one must

* R. M. Johnston Memorial Lecture, Royal Society of Tasmania, 1950.

assume that the earth, like all other matter which has been observed, is subject to the fundamental laws of gravitation, electromagnetic theory, heat conduction, radioactive decay, elasticity and fluid motion. The processes operating within the earth must both obey these laws and also be such as to produce the observed geology of the earth. This assumption is generally agreed upon, but the combined approach by both the geological and the mathematical methods at once, has not been extensively put into practice because geological maps and descriptions are so complex that until recently it was not apparent either to geologists or to mathematicians how the fundamental physical laws could be applied to them.

For more than a century a body of sound geological observation has been growing together with another of established physical laws, but this irreconcilable impasse has existed between them. It is on account of this temporary limitation that geology is often classed as a 'natural' rather than a physical science.

More recently a third class of information has become available in the form of a body of geophysical observations which promise to bridge the gap and make possible the eventual transfer of geology into the group of precise sciences with a sound theoretical basis. These observations include measurements in different parts of the earth of gravity, radioactivity, heat flow, location of earthquakes, age of rocks, layering of the earth's interior. These physical data promise to enable physical theory and geological observations to be reconciled, because on the one hand the geophysical results are relatively simple and amenable to mathematical analysis, and because on the other hand for the first time they tell something precise about the nature of the earth's interior which can be correlated with the surface geology. In this paper published geological and geophysical observations are interpreted in terms of the theoretical analyses of the earth's behaviour advanced by H. Jeffreys (1929) and A. E. Scheidegger (Scheidegger and Wilson, 1950).

The method of approach used has been to examine some existing mountain ranges and island arcs. It has been found that their essential features can be approximated to by simple forms and that the arcs and ranges can be divided into a few classes of elements. These arcs and mountains are generally almost circular arcs. They presumably represent zones where failure has occurred in the outer spherical shells of the earth.

The properties of spherical shells making up various possible earth models of increasing complexity have been examined by Scheidegger to see how such models could fail so as to produce forms similar to those actually observed. Only one has been discovered which would give rise to the required shapes.

It has been shown that there are logical physical reasons why this type of failure not only could, but should, occur. In this manner a mechanism has been derived, which is believed to be physically sound and which appears to be capable of producing arcuate thrust failures at the earth's surface.

This mechanism derived for a single arcuate element is then applied to each part of the present mountain system to demonstrate that its repeated application is consistent with observed geological and geophysical data. Finally, the attempt is made to show that the repeated application of this process in the past might have been sufficient to have built past mountains and to have given rise to continents in a manner consistent with their geological structure.

The paper thus aims to present a coherent theory of the growth of terrestrial features. The theory appears to meet many requirements, but is only a first approximation, for it does not explain the cause of any but the largest structures. An attempt has been made to show that it is quantitatively compatible with the data available from field geology, from geophysical observation and from the pertinent laws of physics. A number of ways in which it may be checked are pointed out.

Characteristics of Active Primary Island and Mountain Arcs and Other Elements of Orogenetic Systems

It is one of the great achievements of field geology to have shown that mountain building is concentrated in mobile active belts which have moved about the earth from time to time. Two belts, each roughly along a great circle, make up the system which is at present active. One of these belts extends across the Mediterranean, Southern Asia, Indonesia, and Melanesia to New Zealand. The other surrounds the Pacific Ocean from Indonesia clockwise to Antarctica. The recognition of this system was largely the work of Suess (Bucher, 1933, p. 33).

It has long been known that many of its elements are arcuate ranges or chains of volcanic islands. Sollas (1903) and Lake (1931) are among those who have suggested that some of these arcs are approximately circular.

In this paper the whole of the present system is regarded as being made up of elements, which may be divided into five classes. Four of these are approximately circular arcs. These five types of arc meet in junctions which also fall into classes, again five in number. These types of elements and junctions will now be described.

Single Island Arcs

Most island festoons such as those of East Asia, the South Sandwich Islands or the greater part of the Aleutian or Lesser Antilles Islands form single island arcs. The essential topographical and geological feature is a regular arcuate chain of active volcanic islands, concentric with which on the outer or convex side is an ocean trench. (Umbgrove, 1947, pp. 173-174.)

Double Island Arcs

If the Aleutian Island arc be followed towards Alaska the single volcanic island arc develops into a double arc; the place of the ocean trench is taken by Chirikof and Kodiak Islands and the Kenai Peninsula, which are all predominantly composed of sediments. The essential topographical and geological feature thus becomes two separate, but parallel arcs of islands, the inner one volcanic, the outer one sedimentary. The arcs near Trinidad in the West Indies and near Timor in the East Indies are other examples of double arcs. (Umbgrove, 1947, pp. 175-177.)

Double Mountain Arcs

If the double island part of the Aleutian Islands be followed still further east, it can be seen to become a double continental mountain system in which the valley occupied by Cook Inlet separates the volcanic (and batholithic) inner arc of the Aleutian Range from the sedimentary outer arc on Kenai Peninsula and in the Chugach Mountains. (Fig. 1.)

Bostock (1948) has illustrated this three-fold division of the western Cordillera for the whole British Columbia coast. Vancouver, Queen Charlotte and Alexander Archipelago Islands are predominantly sedimentary. The main Coast Range in Canade is batholithic and volcanic while between it and the islands is a trough occupied by channels of the sea and patches of flat-lying young sediments.

In the United States a similar double arc divided by a trough is also apparent. The sedimentary Coast Ranges are divided from the volcanic and batholithic arc of the Cascade and Sierra Nevada Mountains by Puget Sound and the Great Valley of California. The whole west coast of North America affords good examples of double mountain arcs, but others are discernible on other continents, as will be shown.

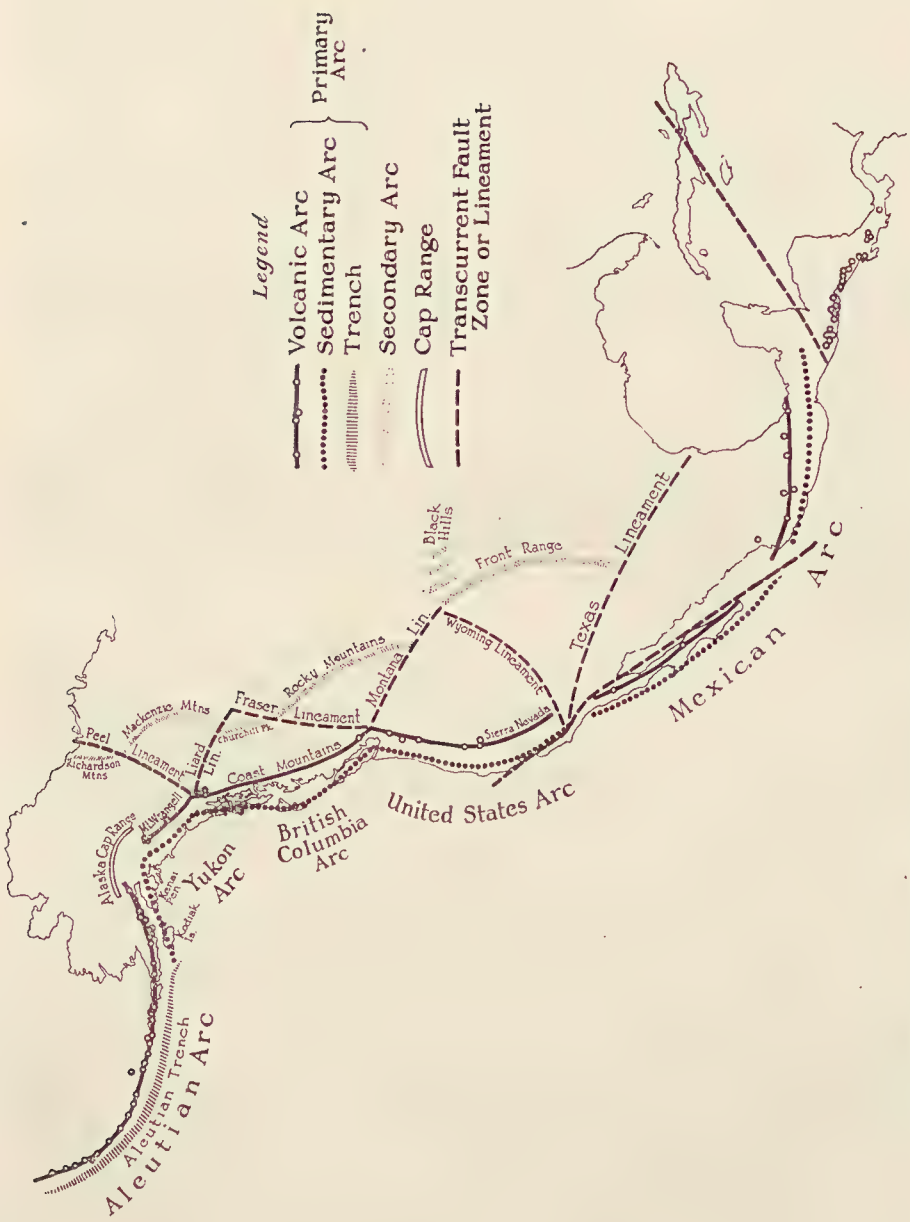

FIG. 1.—The North American Cordillera, showing five primary arcs along the coast, the secondary ranges in the interior, and the medianland which separates them.

Single Mountain Arcs

In the centre of the west coast of South America between Santiago and Ecuador the coastal mountains are volcanic and face an ocean trench off shore. It will be pointed out that the Andes form a series of arcs convex towards the Pacific Ocean. This central part is similar to single island arcs except that the volcanic chain forms part of the continent and includes batholiths as well as volcanoes. The central Andes are the only examples recognized of this type, and the only coastal mountains facing trench off shore. (Fig. 2.)

Fractured Arcs

It is well-known that the San Andreas transcurrent fault zone cuts the southern half of the United States double mountain arc, but it does so without destroying the double arc pattern. In the case of the Philippine fault zone on the other hand, a great fault is the predominant feature and only some disorganized aspects of arcuate structure exist, such as a deep ocean trench, and scattered active volcanoes. The simple arcuate pattern either never existed or has been destroyed or torn apart by the transcurrent fault zone. Such composite features will be called fractured arcs. The arcs from the Philippines to New Zealand are of this general type. (Fig. 3.)

Characteristics of Single and Double Island and Mountain Arcs

The distribution of the four different types of regular arcs (i.e., those other than fractured arcs) suggests that the type developed depends upon the activity of movements along the arc, the age of the arc and the proximity to continents. Single Island arcs are made of young rocks and occur far from continents; double arcs occur where continents are approached; double mountain arcs which may contain ancient rocks are the usual type found upon continents. The single mountain arcs of the central Andes are exceptionally active and are the only mountains with which deep earthquakes are associated.

Gutenberg and Richter (1949) have divided every arcuate structure into six zones lettered A to F from the convex to concave side. These zones together with their possible properties are listed in the following table in a slight amplification of the original statement. Not all of the features are, of course, observed in any one arc. These features are only found in what are here called primary arcs. They are not associated with rift valley ranges nor with secondary arcs like the Rocky Mountains of the Alberta-British Columbia boundary.

FEATURES OF ARCS READING FROM CONVEX TO CONCAVE SIDES

(A) An oceanic trench

(B) An arc of sedimentary islands or mountains
Young serpentine intrusives in the sedimentary belt
Shallow earthquakes under B or on the concave slope of A
A belt of large negative gravity anomalies

(C) A valley or shallow trough between B and D
Earthquakes at depths near 60 kms., frequently large
A belt of positive gravity anomalies

(D) A volcanic island or mountain arc or a batholithic mountain arc
Serpentine intrusives within the volcanic or batholithic arc
Earthquakes at depths of the order of 100 km.

(E) An older volcanic arc
Older Serpentine intrusives
Earthquakes at depths of 200 to 300 km.

(F) Earthquakes at depths of 300 to 700 km.

FIG. 2.—The South American Cordillera, showing four primary arcs of the West Indies and Andes and the secondary ranges which adjoin them.

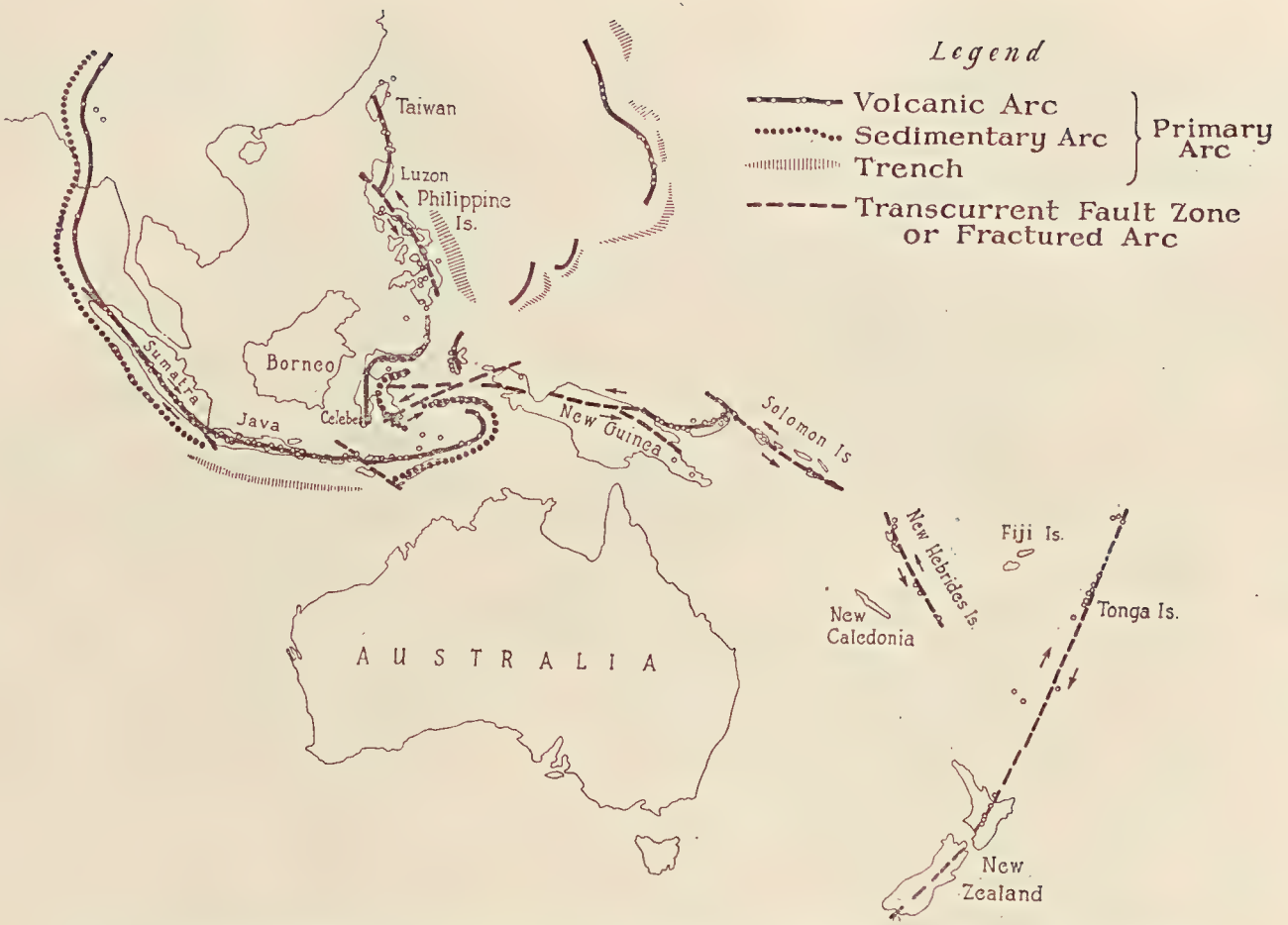

FIG. 3.—The Indonesian junction of orogenic belts and the fractured arcs from the Philippine Islands to New Zealand.

Types of Junctions of Arcs and other Elements of Orogenetic Systems

Linkages, Fractured Deflections, Capped Deflections, Reversal Zones and a few Junctions, of which too little is yet known for them to be classified have been recognized.

Linkages were discussed by Suess and are the kind of junction occurring between the north-east Asian island arcs. They are characterized by the extension of one of the arcs past the junction in a nearly straight extension. This extension is, however, marked by much reduced volcanic and seismic activity and only by shallow earthquakes.

Fractured Deflections are the junctions occurring in North America where two arcs meet in an obtuse angle. One conspicuous lineament and probably a second which is less well developed spring from the junction and enter into the continent forming broad valleys through the cordillera. These valleys are believed to be fault zones and across them are changes in geological structure (Fig. 1.)

Capped Deflections occur where arcs meet at an angle that is right or acute. There is a Cap Range of metamorphic rocks of great elevation swinging around the junction. An example of a cap range is the Alaska range at the junction of the Aleutian and Yukon arcs.

Reversal Zones. When Hess described the West Indies he suggested that the arc of the Antilles was linked to Mexico and to South America by zones of transcurrent faults. Since these zones occur where arcs change from facing in one direction to another, they will be called reversal zones. They have no deep or intermediate earthquakes and appear to be shallow fractures only, and to be approximately straight following great circles. They only occur at either end of the Antilles and South Sandwich arcs.

Other Junctions. This group include junctions covered by the sea such as those in Melanesia, of which little is known.

Theory of Failure of Spherical Shells

The whole of the present system of orogenitic belts might now be described in terms of elements and junctions of the types just defined, but it is considered that this will be clearer if it is deferred until after consideration of the process which is believed to be giving rise to these arcuate and faulted elements.

The simple form which best fits the axis of an island chain or mountain range is not easy to define. Neither topography, geology nor any geophysical measurements yet made give more than an approximate shape. Within these limitations the shape of several arcs has already been analysed. Some appear to be almost straight like the Tonga-Kermadec-New Zealand element, or the Solomon Islands. Most are probably circular, but are possibly spirals not far different from circles. It may be that the centres of most of these circles lie close to one or other of two nearly orthogonal great circles (Lake, 1931, and Wilson, 1949). Certainly most arcs lie at or near the margins of continents. (Fig. 4.)

The development of an arc is presumably due to movement of some kind in one or more of the outer shells of the earth. This can only occur in one of the recognized ways of buckling or failure, that is in an elastic, plastic, creep or flow state or by brittle rupture, sliding fracture or ducile fracture. Shells can fail by expansion or by contraction. The type of failure to be expected has been more fully examined by Scheidegger and the writer from whose paper (Scheidegger and Wilson, 1950) these results are taken.

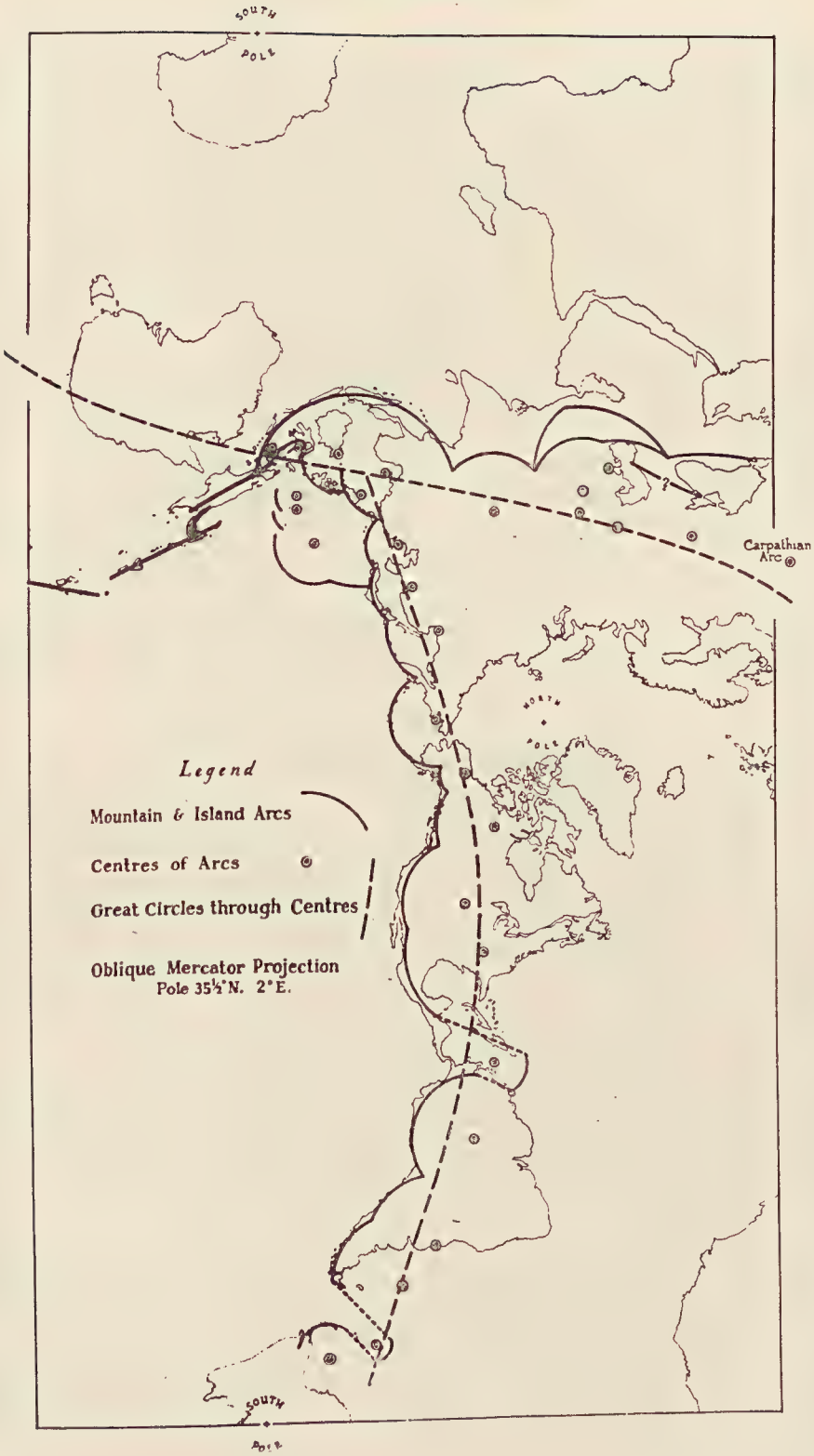

FIG. 4.—The mountain and island arcs of the present orogenic system showing the junction of the two belts in the shape of a "T" at Indonesia.

All possibilities have been investigated for a uniform spherical shell and it has been shown that a uniform shell could not fail so as to form either an arc or a spiral. The earth, however, is not uniform. When the case of aspherical shell with a point of weakness was examined two possibilities were found by Scheidegger which might provide an explanation for the formation of arcs. If a shell with a point of weakness failed in a plastic state it would form a double family of slip lines each with the shape of a logarithmic spiral. These slip lines might be correlated with arcs on the earth's surface, although this is rather doubtful.

However, a spherical shell with a point of weakness could under different stress conditions also fail by sliding fracture, in which case it could break along a conical surface, with the point of weakness as centre, dipping inwards at about 45°. This would be a single fracture not a member of a family, but there could be a number of points of weakness and hence a number of fractures each intersecting the surface along an arc. Such fractures would be ruptures and if their surface expressions took the form of island or mountain arcs then the surfaces of rupture would coincide with the known location of shallow and deep earthquakes and so would be suitable for explaining the cause of shocks. This then appears to be a possible physical explanation and may be tentatively adopted, but it is necessary to show what could cause it. This will be attempted in the succeeding section.

This investigation was not carried further. More complex assumptions could be made, but that is perhaps unnecessary until this simplest explanation has been shown to be untenable.

A reason for the existence of a few irregular elements (Fractured arcs) will be advanced when the whole system is described since their cause depends upon the interaction of parts of the whole system.

The Cause of Failure of Shells Within the Earth

The earth is generally considered to be a heat engine generating about 33×10^9 H.P. as estimated from heat flow and 5×10^9 H.P. as estimated from the energy of earthquakes (Gutenberg and Richter, 1949, pp. 20-21). According to Griggs only two primary mechanisms have been suggested which are adequate to cause mountain building. These are 'compression due to thermal contraction and viscous drag of convection currents in the substratum'. (Griggs, 1939, p. 618.) Many geologists and physicists hold that convection currents provide a likely explanation. Griggs (1939) and Vening Meinesz (1948) have shown very well how convection currents could provide an explanation of the cross section of mountain ranges, but it must be remembered that diagrams of cross sections include various assumptions and that the theory of convection currents is not proven until an explanation is also presented of the development in plan of a series of island arcs. Scheidegger doubts if currents could produce the pattern of arcs. Recent determinations in the Canadian Shield of radioactivity and heat flow are much less than the figures usually taken for the crust. Also large gravity anomalies have been found there which make this theory less tenable than it was formerly held to be.

In this paper an explanation of many features of the earth's surface has been developed which is believed to be physically sound. It has been found that it can be based upon Jeffrey's statement of the contraction hypothesis (Jeffreys 1929, pp. 138-160), but not upon any idea of convection currents.

If the earth is cooling and contracting by conduction and radiation there must be a level of no strain above which the rocks are in compression and below which they are in tension. Jeffreys placed the level of no strain very approximately at 100 km and the limit of appreciable cooling at 700 km.

Recently, Benioff (1949) using data supplied by Gutenberg and Richter has shown that the earthquakes occurring beneath the Andes and Tonga-Kermadec Islands not only lie on surfaces extending to depths of 700 km., but also may be divided into two sequences lying respectively above and below a discontinuity at 70 km. across which he gives reason to believe that there is no effective mechanical coupling. If Jeffrey's very approximate estimate of 100 km. is equated to Benioff's observed depth of 70 km. an explanation of Benioff's observations is provided by the supposition of a cooling earth with a level of no strain at that depth separating the deep and shallow shocks. (Fig. 5.)

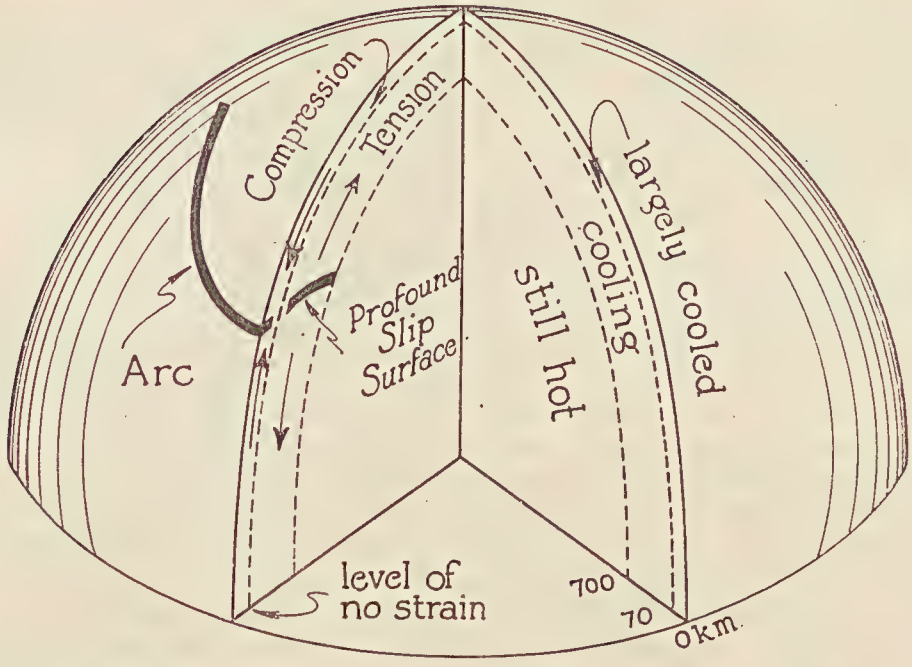

Fig. 5.—Sliding fracture along two conical surfaces centred about a weak point as the cause of arcute failure upon the surface of a cooling earth.

The shell from 70 to 700 km. would be contracting due to cooling, which would cause it either to be in tension or subject to a relief of pressure and hence to fail by sliding rupture producing normal faults with a conical form centered about points of weakness and with a dip of over 45°. It is the cooling of this deeper layer which is regarded as the prime cause of the earth's motions. Above 70 km. the shell would be in compression and would fail by thrust faults with a dip of less than 45°.

Where there are deep and shallow earthquakes their position shows that, in general, failure in the shallow zone overlies failure in the deeper zone. This is not coincidence and apparently the upper failure is constrained to lie over the lower in spite of the theoretical and observed lack of mechanical coupling between the earthquakes occurring in the two layers (Benioff, 1949, p. 1844). The distinction between the forces which are uniform in all directions in the lower layer and the directed forces in the upper layer is important and will be discussed later.

According to the analyses already made arcuate failure must be due to forces which are uniform in all directions. On the other hand, some of the smaller structures and notably the echelon folds and lines of volcanoes on the Japanese islands are not arcuate. They are straight and parallel, and strike not around each arc but along the orogenetic belt as a whole (Tokuda, 1926, and Wilson, 1950).

An explanation of this difference is afforded if one considers the primary cause of mountain building to be world wide cooling, with resultant tensions by forces uniform in all directions in the deeper layer. Deep fracturing having occurred, the shallow fracturing is not due to a world wide and uniform system of forces but is due to local forces which constrain it to occur above the deep fractures and to be oriented with a major axis of stress perpendicular to the deep fractures. In this case failures would not be expected to be arcuate. They would be straight and would appear either as a series of small folds constrained to lie along an arc over the deeper fractures, with each fold axis normal to the major axis of stress in the upper layer, or else as a series of approximately 45° transcurrent faults such as those forming the lineaments connected with fractured deflections. In any case the occurrence in the same arcuate element of large scale features due to tension and also smaller features due to compression is easily understandable. This occurrence of tension and compression features in the same mountain range has been noticed by many previous writers (e.g., Bucher, 1933). The above explanation which places them one above the other avoids having to devise a mechanism involving alternating periods of tension and compression.

Thus, an explanation has been advanced for the building of arcuate, folded mountains and for the occurrence of earthquakes beneath them. Shallow and deep earthquakes occurring on the same arc should have opposite directions of first motion being due to thrust and normal faults respectively. This has been observed and is capable of being further checked (Byerley and Evernden, 1949).

It is considered that ocean trenches are due to overriding by the inner block up-thrust at the surface. If the fault zone is active and far from continental sources of detritus the trench may remain open, but in other circumstances the trench may become filled and subsequent motion may push up the sedimentary filling in the form of thick, contorted, marine beds which may rise above the sea to form an outer sedimentary arc. The same overriding and underthrusting probably suffice to explain the occurrence and position of the belts of negative and positive gravity anomalies. This explanation appears to be very similar in appearance to that shown by Umbgrove (1947, Fig. 114, p. 174) although the postulated cause is different. Certainly Vening Meinesz' concept of the downward root or tectogene has been most valuable.

The cause of the persistent occurrence of volcanoes over that part of the fault surfaces lying about 100 to 150 km. deep is not known, but it is possible to imagine an explanation compatible with the rest of this theory.

The General Characteristics of an Orogenetic System

The principle characteristics of the arcs of the present active orogenetic system will now be described. The six features of a primary arc which were lettered A to F by Gutenberg and Richter have already been mentioned (see Table, p. 89), but primary arcs are only one of several parts that may be present in an orogenetic system. In any cross-section of the North American Cordillera from west to east the following zones are present separated in the manner indicated.

Foreland. The Pacific Ocean basin

Boundary. Sole of thrust fault zone of primary arc dipping east.

Primary Arc. The Coast Range Mountain System including the St. Elias and the Coast Ranges, Cascade Mountains and Sierra Nevada.

Boundary. Indefinite or unknown boundary.

Medianland. The Central Plateau and Basin and Range Province.

Boundary. Faults of the Rocky Mountain Trench.

Secondary Arcs. The Rocky Mountain system.

Boundary. Sole of thrust fault zone of secondary arcs dipping west.

Hinterland. The covered shield and Canadian Shield.

All these zones, or at least the first, second and last ones, will be shown to be present in every section across an orogenetic system which is taken in the direction from the convex towards the concave side of the primary arc.

The foreland is always on the convex side of the primary arc. It is often an ocean, but may be a shield as in the case of India, Arabia and Africa.

The medianland corresponds to the Zwischengebirge or median mass and may or may not be present. If not, the primary and secondary arcs fit together as do the western (primary) and eastern (secondary) Andes.

The secondary arcs may always be distinguished from the primary arcs by reason of their lack of any appreciable volcanism or igneous intrusion, which are indispensible features of any primary arc. They are younger than primary arcs and have no deep earthquakes as can be observed when they are separated from primary arcs by a medianland.

The hinterland is always a shield, usually largely covered, to which the secondary but not the primary arc is convex.

It is suspected that Kyrnine's three classes of sedimentary rocks often fit this structural classification and that his greywacke, arkose and quartzite classes are associated respectively with primary arcs, secondary arcs and thinly covered hinterlands. (Kyrnine, 1948.)

The Present Orogenetic System

North American Arcs

The Foreland is the Pacific Ocean Basin.

The Primary or Western Arc of the North American Cordillera between Alaska and Honduras consists of four double mountain arcs. These are the Yukon, British Columbia, United States and Mexican arcs which meet in fractured deflections opposite to Skagway, Seattle and Los Angeles. They are illustrated in Fig. 1 and the principle features are self-explanatory. The position of the Mexican arc was established with the aid of the locations given by Gutenberg and Richter (1949, p. 36) for shallow earthquakes and for the position of the large negative gravity anomalies which have been found by submarine off the Lower California coast.

The Medianland is present in North America and forms the Interior System of Yukon and British Columbia (Bostock, 1948) and the Basin and Range and the Plateau Provinces in United States. It is, of course, a very complex area in which metamorphic and igneous rocks are abundant.

The Secondary Arcs are the Eastern System, Rocky Mountains or Front Ranges of the Cordillera and are divided into six ranges or groups of ranges all without appreciable recent igneous activity. The three principle of these form great circular arcs well shown on the tectonic maps of Canada and United States (King, 1944,

and Derry, 1950) and are the Mackenzie Mountains, the Rocky Mountains of British Columbia-Alberta-Montana and the Front Ranges of Wyoming, Colorado and New Mexico. Alternating with them are the smaller Richardson Mountains, Churchill Peak Rockies and the complex of mountains in southern Montana. All these features are probably confined to the shell above the level of no strain.

The Hinterland is the Canadian Shield together with covered parts of it in the Interior Plains.

Lineaments

The two lineaments springing from each of the three fractured deflections are shown on Fig. 1, p. 89. In each case that one striking ESE is the only one to be well developed. Of these six lineaments the two most southern were described by Ransome (1915), the Montana lineament is well known to those working in Montana (e.g., W. T. Thom and E. S. Sampson) and there is evidence along some of the faults along this last lineament that the south side moved east. The three marked in Canada possess similar properties and directions to those in United States but have not been so widely recognized.

All six are valleys, marked by rivers and transportation routes. Along the better known there are evidences of fault zones. Where they cross the Cordillera many other structures either change direction or end abruptly. One of the strongest reasons for believing in the validity of these large indefinite features is the marked changes which occur in the secondary arcs of the Rocky Mountains where the lineaments cross these secondary mountains. The precision with which the secondary arcs stop at lineaments and with which changes in direction of the Rocky Mountain trench occur at lineaments can be checked on the tectonic maps of Canada and United States.

The pattern illustrated in Fig. 1 has such astonishing regularity that it cannot be due to chance. Some geologists may claim that it is only obtained by gross over simplification and by associating features not of precisely the same age and of such dissimilar nature as the Sierra Nevada and Cascade Mountains. On the other hand, a physicist would be likely to suspect any explanation that was not fundamentally simple. This may therefore serve as a first approximation whose discrepancies from the complexities of geology need further explanation.

We have already suggested that the reason for the arcuate nature of the primary arcs lies in contraction below 70 km. which is uniform in all directions and symmetrical about weak points and that failure occurs on conical fractures. Once this deep failure has occurred a major principle axis of stress is set up normal to the belt, which gives rise to vertical sliding fractures cutting the belt obliquely. This is suggested as the cause of the lineaments. If true their directions of motion are known from theory and can be checked in the field. It is suggested the lineaments only occur in the upper shell. Deep earthquakes do not occur along them.

It has been shown that the same forces normal to the orogenetic belt would also explain the echelon structure of the Japanese islands as folds or thrusts. Such an echelon arrangement of the volcanic peaks of the Cascade Range is quite apparent on the Tectonic map of United States. (Wilson, 1950, pp. 147-150, and King, 1942.)

On the other hand, directional surface forces would not explain the plainly circular shapes of the three main secondary arcs. This is an anomaly which is not understood, but it may be pointed out that these three main secondary arcs have their centres approximately at the centres of the fractured deflections which might conceivably have acted as points of weakness.

The Andean Arcs

The Foreland is the Pacific Ocean (Fig. 2).

The Primary Arc consists of three mountain arcs in the Andes. One junction at about 19° south is obvious enough and Benioff (1949, p. 1854) has pointed to a change in earthquake distribution there. The other at Santiago is 33° S is marked by eastward branching folds (Oppenheim, 1948), shallow earthquakes in the interior (Gutenberg and Richter, 1949, p. 42) and a pass. The northern junction is a capped deflection with the Puna block of high (21,000 feet) metamorphic mountains forming the cap. The southern junction is perhaps a fractured deflection.

There is an interesting division of the Andes into single and double types of arc. From Tierra del Fuego to Santiago there is an outer fringe of island or a coastal range composed of in large part of metamorphic or sedimentary rocks, and partly of unexplored nature.

North of Santiago 'longitudinal structural depressions such as the Vale of Chile do not exist and highlands continue unbroken though with gradually decreasing elevation from the Andean front westward to the ocean' (Rich, 1942, p. 165), but from the Gulfs of Guayaquil to Maracaibo there is again an outer sedimentary arc. The central region of single mountain arc is fronted by an ocean trench and is the only part that is underlain by deep earthquakes. There are large negative gravity anomalies off shore approximately over the trench (Gutenberg and Richter, 1949, p. 40).

The Medianland is not present. In the Andes there is clearly no Medianland and the primary and *Secondary Ranges* lie side by side, the reversed convexity and alternating cusps allowing them to fit closely together.

Oppenheim divides the whole length of the Andes into two provinces of which the western ranges are those we have described. They are 'formed totally, or in some instances partly, by great masses of igneous rocks' and were uplifted mostly by block faulting in Upper Mesozoic and Tertiary stages. 'In contrast with the western Cordilleras the eastern ranges of the Andes are formed mainly by sedimentary and metamorphic rocks with the crystalline core appearing in long stretches . . . The structure of the eastern ranges is also predominantly normally faulted and folded; however, moderate thrust faults evidently occur in the easternmost ranges mainly facing the basin plains to the east . . . The age is mainly late Tertiary and Quaternary'. This description suggests that the eastern ranges are the secondary ranges corresponding to the Rocky Mountains in North America and like them younger, sedimentary, and overthrust towards the east. (Oppenheim, 1947, pp. 171-172.)

The Hinterland is the shield areas of eastern South America and their covered extensions adjoining the Andes.

The East Asia Festoons

Off the east coast of Asia between Alaska and the Philippine Islands are the best developed systems of island arcs in the world. The principle of these form the five regular festoons of the Aleutian, Kurile, Japanese, Ryukyu (or Nansei) Islands and the arc from Taiwan (Formosa) to Luzon. Hess (1948, p. 442) has stated that the three southern arcs underwent a major deformation in mid-Mesozoic time.

In late Cretaceous time the pattern of failure changed and since then the most active zone has followed the Kurile Islands, crossed Japan by the Fossa Magna and followed the Bonin, Marianna, West Caroline and Palau Islands. (Fig. 6.)

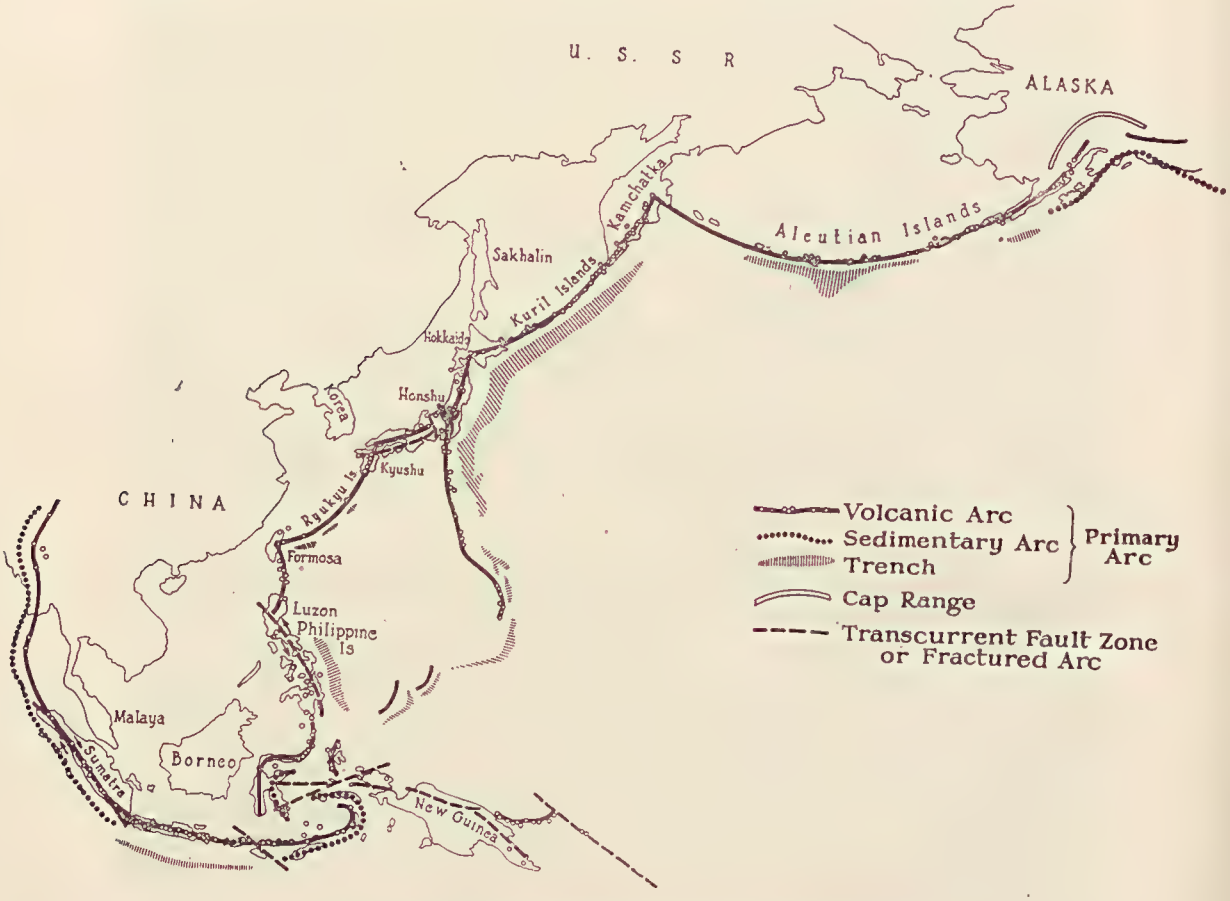

FIG. 6.—The East Asian primary arcs and the Indonesian junction.

Consider first the older belt and notice the similarities and differences between the five arcs. It will be assumed that the Kurile and Aleutian arcs did form in mid-Mesozoic time when the Japanese and North American arcs between which they lie underwent great deformations. There is no evidence known to the contrary. Symmetry suggests it for at the present time the belts of young and active mountains form continuous unbroken belts around major parts of the earth. Therefore it is reasonable to assume that in Jurassic time also the belts were continuous.

The five older arcs, with the possible exception of Japan, appear to be single volcanic arcs and all lie along the margin of the continental shelf about the same distance offshore, between oceanic deeps and moderately shallow water. The form of union between them in each case is linkage with a knot of volcanic mountains at each point of union. These knots are respectively the Sopka Klyuchevskaya volcanoes (15,912 feet) of eastern Kamchatka and the islands of Hokkaido, Kyushu and Taiwan.

Systematic differences between the northern and southern arcs are that the arcs grow smaller towards the south and the knots become increasingly detached from the continent. In regard to these connections with the continent it has already been indicated that the Aleutian peninsula and mountains are part of the volcanic arc right up to the Alaska cap range, but that in the case of the Kamchatka and Hokkaido junctions the active earthquake zones follow the arcs and that there is little seismic activity and no deep activity along the northern half of Kamchatka nor along Sakhalin. It is considered that these extensions in northern Kamchatka and Sakhalin correspond to the lineaments of the fractured deflections in North America and very likely have transcurrent fault zones with left hand (anti-clockwise) displacements along them. This supposition could be checked.

The younger belt and its relation to the five arcs just discussed is most interesting. The evidence of deep earthquakes shows that to-day the primary deep-seated failure follows the Aleutian arc (where there is a little intermediate activity and much volcanism) and the Kurile arc, but instead of turning along the Japanese arc as do all of the shallow features (trench, volcanoes, shallow shocks and geological features) the deep shocks continue along an extension of the Kurile arc to the Asiatic coast near Vladivostok where they join with deep shocks lying upon a continuation of the Bonin arc. This arc crosses Japan by the Fossa Magna. The shallow features all follow the Japanese Islands from the Kurile arc to the Fossa Magna where they divide. The more active volcanoes, the deeper trench and the larger shallow shocks turn along the Bonin, Marianna, West Carolines and Palau arcs with the deep shocks, but some weaker features continue to follow the old arc. This is interpreted as a case where transition from one arc to another is only partially completed. The fact that the deep earthquakes follow a different path from the Kuriles to the Bonins from that followed by the shallow shocks seems to support Benioff's observation that there is no mechanical coupling between the shallow and deep earthquakes and that it is not inevitable that shallow failure will be over deep failure. This also is quite in harmony with the interpretation already given.

The cause and occurrence of echelon structures have already been discussed. It is obvious that the change in location of the profound normal faults which took place early in Tertiary time should have been accompanied by the start of a new echelon pattern. Inquiry shows that this pattern exists and is illustrated by Tokuda (1926, Fig. 7B). A series of 3 block mountains cross central Japan along the Fossa Magna and their echelon structure is continued for at least a little way along the Bonin arc by a series of volcanic chainlets. As far as the writer can understand the age of this second echelon pattern is Tertiary and younger in origin than the Jurassic age of the other echelon structures.

Tokuda's interesting experiments in forming similar echelon patterns by pushing his finger tip across wet rice paper is compatible with the explanation given, for his finger tip constrained the echelon folds to form in an arc around it.

The Alpine-Himalayan-Indonesian-Oceanic Belt

The arcs and ranges dealt with thus far have been relatively simple. They form one of the two belts which lie around the earth. The existence and general trend of the mountain ranges and island arcs are so clear and well-known that only details can differ. Whether the right features have been chosen for emphasis and whether the explanations given have been satisfactory are the only points for discussion.

With the other belt of young mountain and island arcs the situation is not comparable. Many of them are so complex and irregular that even the broadest generalizations are difficult and uncertain. The writer has none of the detailed knowledge which would be required to enter into an adequate discussion of the structure of these regions. On the other hand, to have attempted to give an explanation of the simple belt without giving any reason for the complexity of the other one would weaken the whole case which has been put forward.

A very brief attempt will therefore be made to give reasons why complexities exist and to show that some of the irregularity is more apparent than fundamental.

The Himalayan and Alpine mountains will be treated first, then the arcs of the south-west Pacific and finally the Indonesian junction.

The Alpine-Himalayan Mountains. One factor believed to produce complexity of the mountain chains in this region is the abundant supply of sediment available from Asia, India and Arabia in the Himalayan region and from both Europe and Africa in the Alpine region.

Another factor generally considered to be important is the close proximity of older ranges. Reference to Umbgrove (1947, Plates 2 and 4) shows that in the circum-Pacific belt Paleozoic folding is only close to later folding in Bolivia and Japan. On the other hand, the whole Himalayan-Alpine belt parallels a similar important belt of Variscan age that lies immediately to the north.

A third factor is that this belt did not have open ocean on either side of it. All the circum-Pacific belt fronts on the Pacific ocean, but the Tethys geosyncline was a trough between Eurasia on one side and Africa, Arabia and India on the other. At the eastern end the main Himalayan range lies entirely south of the older folding, but at the western end the Alpine folds have been superimposed directly against the Variscan belts. The consequences of this have been dealt with at length by Bucher (1933, esp. Fig. 88, and Law 39, p. 389) and are summed up by Umbgrove (1947, p. 298) as follows: ' Perhaps we may understand the otherwise incomprehensible knot of Alpine chains in the surroundings of the Mediterranean as partly due to the influence of some very old lineaments. Though deeply buried, they still actively exercise their modelling power on the Tertiary mountain chains '.

Unfortunately, we can obtain no guidance about the nature of the deep-seated failure as there are few intermediate and no deep earthquakes. The deep-seated arcs could be more regular than the surface ones. This also has made it more difficult to trace the primary arcs. Nevertheless, as in North America, it has been possible to identify a series of primary arcs each marked by outer sedimentary ranges and inner volcanic and batholithic ones, and also a series of medianlands and a series of secondary shallow-water sedimentary arcs. These features are of course, all well-known.

It is suggested that there are five great primary arcs (Fig. 7), some rather fractured and irregular, but all possessing the usual features and all about the size of the Aleutians. These all meet in capped deflections. The primary arcs are the Indonesian Arc, the Himalayan arc, the Persian arc, the East Mediterranean arc and the West Mediterranean arc. The cap ranges are the Alps, the Caucasus, the Pamir and some of the high curved mountains of the Ta shuch shan on the Burma-China boundary. All these primary arcs are convex to the south and therefore Africa, Arabia and India are forelands whereas Eurasia is the hinterland for all the arcs. Secondary arcs, thrust to the northward and lacking volcanism, are the Pyrennes, Carpathians, Pontic, north Persian and perhaps the Karakoram Mountains. These are naturally connected with some of the cap ranges since cap ranges are but parts of the secondary system.

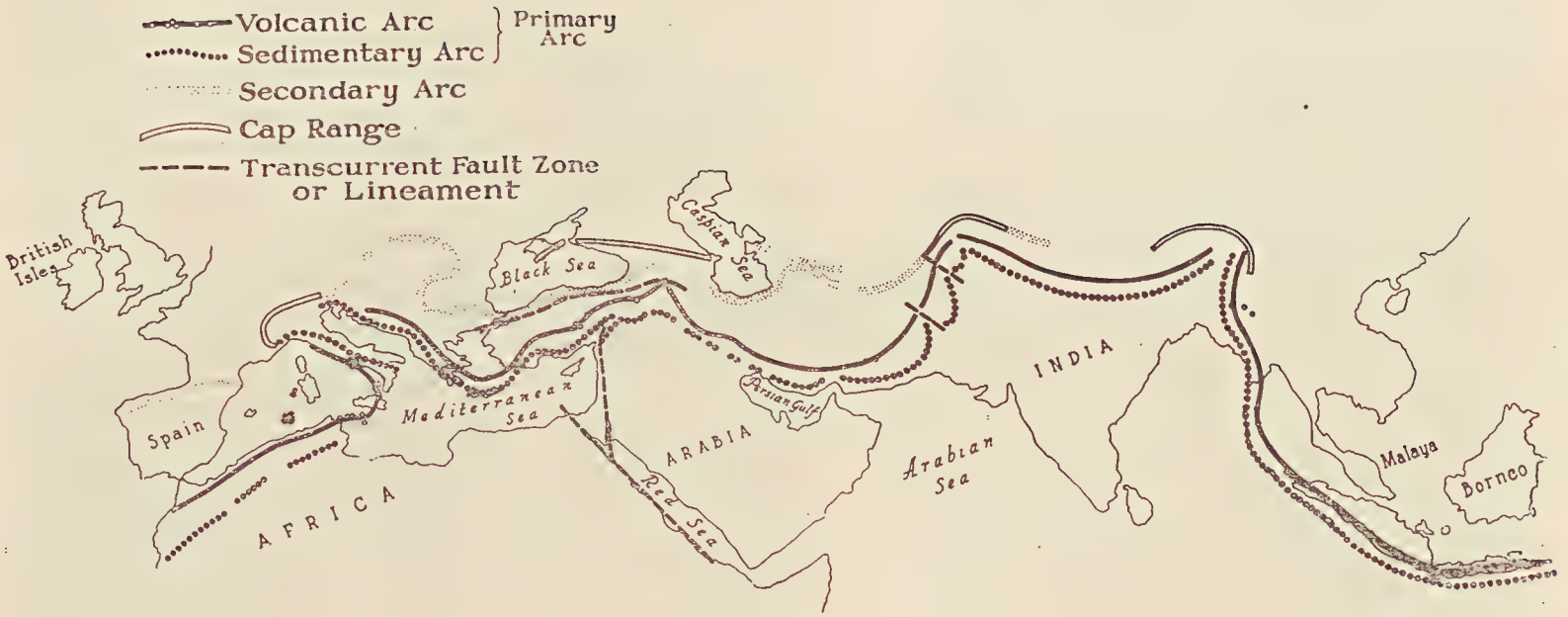

FIG. 7.—The East and West Mediterranean, Persian, Himalayan and Indonesian primary arcs. The rocks of the volcanic arc are andesitic to granitic, those of the sedimentary arc are ophiolitic.

The Melanesian Arcs. These arcs which may be considered to extend from New Guinea to New Zealand include some of the most active seismic regions of the world and certainly the most irregular arcs (Fig. 3). They are not merely compound ones like those discussed in the last section, but some are reversed in direction to others and have ocean deeps on the concave instead of the convex side, and some depart greatly from the normal size by being either very small, like the New Britain arc, or long and almost without curvature, like the Tonga-Kermadec arc.

The three reasons advanced as explanations for the complexity of the Alpine-Himalayan ranges do not apply for there is no evidence of abundant sediments nor of previous orogeny nor of continents on both sides. Some other explanation must be sought.

The one proposed is that the Melanesian arc is part of both the principle belts and has partaken of the fundamental movements of each. The direction of motion in the two belts is nearly at right angles and the interaction of these forces has caused the complexity.

This can be seen by reference to Fig. 8 in which the two belts are shown diagrammatically. Along two of the three limbs of the 'T', shrinking below the level of no strain and compression above can take place without shearing, but along the third side shearing must accompany the shrinkage or compression. This can be seen by arranging three books in the same way separated by one inch gaps and then moving them together or apart.

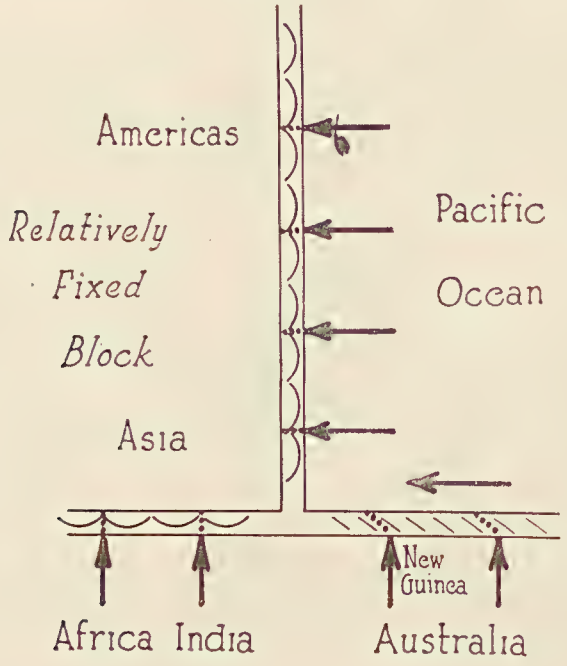

FIG. 8.—Diagram to illustrate the shearing in one limb of the orogenic system, which is believed to be the cause of the fractured arcs from the Philippine Islands to New Zealand. Compare with FIG. 4 (inverted).

We have seen that tension failure alone in the lower shell gives rise to a series of sliding fractures along conical fractures with arcuate outcrops. But if shearing is occurring at the same time conical fractures cannot form and nearly straight fractures take their place.

This is suggested as the explanation of the fractured arcs of the Philippines, New Guinea, Solomon Islands and New Hebrides Islands. It is easy to suggest more precise details of probable direction of motion, but data are limited. The location of active volcanoes and of recent earthquakes is known and they fix the approximate location of the arcs, but the direction of motion of the earthquakes, the distribution of gravity anomalies and the geology are not well known. There is such disagreement about the structural interpretation even among the best informed authorities upon the region. Rather than indulge in speculation, it is just suggested that the occurrence of irregular and straight arcs in this region was to be expected. A mechanism believed to be capable of explaining them in detail when more information is available has been advanced.

Concerning the broad interpretation of the geology of New Zealand and its connection with the Tonga-Kermadec seismic belt and with New Caledonia and other islands there seems to be rather pronounced disagreement at the present time. Suffice it to say that H. Wellman (1950) has identified a longitudinal fault with a lateral displacement of 200 miles. If this is substantiated it is a very large example of the type of structure proposed for New Zealand and the Melanesian fractured arcs.

The Indonesian Junction of Belts. The only thing that can be said briefly about the area of junction of the two belts is that it is complex because two sets of forces acting nearly at right angles have acted upon every part and two belts of failure meet there. It is not surprising therefore, that features often partake of a double nature and that they are broken and irregular.

General Features of the Mesozoic-Cenozoic Pattern of Failure in the Earth

Some of the component arcs and important features of the two Mesozoic-Cenozoic belts have been described. They have three distinguishing features. They are constituted of ranges of folded mountains and volcanic island arcs. They form continuous belts of failure about the earth. They are all generally contemporaneous having been formed during the last 2×10^8 years which is only six per cent of the time since the origin of the earth (Holmes, 1949).

Although these features are the only folded and arcuate volcanic structures of that age, they are not the only features presumed to be due to disturbance of the crust during recent time. There are other kinds of disturbance of which the most important systems are perhaps the African Rift Valleys, the North Atlantic or Thulean volcanic system, the Hawaiian Islands and other linearly arranged Pacific Islands (Chubb, 1934). It is interesting to notice that all of these features have the following points in common. They are all far removed from the arcuate systems; they have only shallow seismic activity associated with them and their volcanic rocks are basaltic, whereas those of the arcs are andesitic.

It is suggested that all these features other than the arcs are due to predominantly horizontal adjustment of the upper part of the crust made necessary by the folding and contraction occurring along the orogenic belts, because the occurrence of shallow but no deep earthquakes in conjunction with these features shows that they have no profound slip-surfaces beneath them. This suggests that they have only extended deep enough to tap basaltic magma and that more profound sources are those which give rise to more acid solutions and magmas. If these are due to horizontal adjustment, that would explain the frequency of long straight faults and lines in their pattern (Anderson, 1942). The Atlantic Ridge could conceivably represent a zone of crustal adjustment also, although, its arcuate shape suggests that it may be a belt of orogenic failure. Its age is not known. Detailed investigation of its structure has only been started (Tolstoy and Ewing, 1949).

The two Mesozoic-Cenozoic orogenic belts are broadly speaking contemporaneous, but there is no evidence that all parts have behaved in the same manner at the same time. On the contrary, those parts where deep-earthquakes are now occurring are considered to be active at present. Other parts like the west coast of the United States are relatively quiescent. It is held with Rutten (1949) and Gilluly that this has been the general rule, that each arc may have had its own history of deposition and erosion and local orogeny and that orogenic epochs within the framework of these Mesozoic-Cenozoic belts have not necessarily been contemporaneous all over the world. As Gilluly (1949, p. 588) stated in his Presidential address to the Geological Society of America 'It seems reasonable to take the California record at its face value, as indicating uplift at one place or another almost continually throughout the Cenozoic. Such movements were doubtless sporadic, like the modern faulting that causes earthquakes. They proceed now quickly, now slowly, now in this area, now in that'.

Benioff's study of earthquakes suggests that in any one arc movements have been contemporaneous, but that there is less regularity in crustal than in profound movements and that there is some connection between adjoining arcs. No doubt there is usually more parallelism in the history of adjacent arcs than between those far apart.

Paleozoic and Precambrian Orogenic Belts

So far only the youngest orogenic belts have been discussed. The idea that the Mesozoic-Cenozoic orogenic episode is but the latest of several is well known. Jeffreys (1929, p. 282-285) has suggested that there may have been of the order of five orogenic epochs. Holmes (1946, p. 109) from geological evidence, which is scarce in the Precambrian, has dated nine, Wahl (1949) and Sonder (1947, p. 941-944) believe there have been a dozen such cycles in the last 2000 million years.

These ideas are followed here and held to be the method by which geological history has unfolded and continents have grown. Only one brief attempt to describe any older belts can be made here. The full story would indeed include all geological history. Sketches of the two Paleozoic belts have been given by Umbgrove (1947, Pls. 1 and 2). Recent views about belts in the Precambrian, have been given for Africa by Stille (1943) and Holmes, Leland and Nier (1950a) for Australia by Hills (1948), for India by Krishnan (1948) and Holmes, Leland and Nier (1950b) and for Canada by Gill (1949) and Wilson (1949b). The idea which has been suggested in different forms by Davison (1887), Andrews (1916) and Lawson (1932) that continents are growing and that they are made up of the belts of past failure is thus well established.

From Umbgrove's maps (Umbgrove, 1947, Plates 1-5) it can be seen that the older belts tended to form on the margins of continental nuclei. These nuclei were smaller and more numerous then. The belts had more branches to fit these smaller nuclei. In some places successive belts paralleled each other, in other parts they were on different coasts and intersected.

The reason why the belts of failure migrated every few hundred million years can perhaps be explained. Orogeny alters and consolidates those marginal shelves which form belts of weakness and initiate one orogenic system, while other coasts are being weakened by deposition. Failure relieves stress along the belt of failure but other stresses may build up elsewhere. These two processes, the formation of new belts of weakness and the creation of stress in new localities, lead to migration. It is not clear to what extent movement of belts is a worldwide movement and to what extent it occurs irregularly. It is certain that in the Triassic period the Appalachian region ceased to be an area of active orogeny. This seems

to indicate a sudden and complete movement of the orogenic belt. Following this halt in the east there was great activity in the western Cordillera during the Jurassic.

It is not known how these earlier belts connected from one continent to the next, but until evidence of submerged island arcs is found, it must be supposed that former connections followed those now existing across Indonesia, Bering Strait, the Caribbean region and Drake Strait. The possibility that some former connections were in the form of large reversed arcs makes then harder to locate. The fact that at these places where continents approach one another there are islands with exposures of old rocks suggests that the present connections have been used before (e.g., St. Lawrence Island near Bering Strait and South Orkney Islands near Cape Horn both contain Lower Paleozoic or Precambrian rocks).

The mechanism which has been propounded allows for there to be a broad similarity in the history of each great system of belts, a closer contemporaneity in the events of each arc and between adjacent arcs, but it does not demand any world-wide periodicty of diatrophism.

As Rutten (1949, p. 1769) concluded 'Instead of worldwide, synchronic, orogenetic revolutions, there thus have been periods of long duration, characterized by varying and fluctuating tectonic activity. The active periods are not world-wide. While part of the earth was in tectonic rest, elsewhere tectonic activity was found. The quiet regions may have already been folded during an earlier date, or they will be folded at a later date, or they may remain ultimately undisturbed. Differences in time of folding may be found not only in different continents, but also along one and the same orogenitic belt'.

It is considered that the continents are entirely built up from the roots of former primary orogenies. The idea that they have grown thus since Precambrian time is already widely accepted. (Holmes, 1946, p. 401). The principle of uniformitarianism suggests that the same processes went on in Precambrian time (Sonder, 1947). In three papers preliminary to this one the writer has endeavoured to show that the concept that continents have entirely grown during geological time is compatible with the geological, cosmological and geophysical evidence in the Canadian Shield. (Wilson, 1949b, 1949c, and 1950.) The old idea that the continental basement is an original sialic block finds no support from Precambrian geology.

Since it is well known that mountains usually form in thick geosynclinal deposits of sediments it will be well to examine next the rate at which such belts have originated and been changed into ranges. We must, in fact, examine the source, and rate of accumulation of the material that enabled continents to grow.

The Rates of Erosion and of Deposition

It has been estimated that erosion reduces the surface of the United States by one foot in 9000 years. (Dole and Stabler, 1909.) If this process had continued at the same rate throughout the length of geological time a layer about 17 km. thick would have been removed since the beginning of Paleozoic time (5×10^8 years) and 110 km. thick since the probable time of origin of the earth (33×10^8 years). For comparison, the thickness of the whole crustal layer above the Mohorovicic discontinuity is only about 30-40 km.

It has been suggested that the present rate is high, so that a better measure is provided by figures recently published by Murray (1950), giving the volumes of sediment deposited on the Gulf Coast in Mesozoic and Cenozoic time.

If we accept from Murray's data that the emerged and off-shore portions of the Gulf Coastal Plain together contain at least 500,000 cubic miles of Cretaceous and later sediments and also that this was accumulated during 130 million years

from an area of 1½ million square miles then the rate of erosion would have been about 1 foot per 85,000 years. But this takes no account of the sediments swept out to the deep ocean and the floor of the Gulf of Mexico. Kuenen (1941, p. 174) has shown that the volume of deep sea deposits may be three times as great as the corresponding volume of continental sediments.

We need not discuss this in more detail but can safely conclude, that the rate of erosion is such that it removes a foot in not more than each few tens of thousands of years off continents in a similar state to North America.

The important point is that if erosion at all comparable to that of Mesozoic and Cenozoic time had taken place in Paleozoic and Precambrian time then there would exist shelves of those ages around North America many times as extensive as those of the Gulf coast. Of course, no such shelves exist. Except for the Atlantic and Gulf Coast shelves there are virtually none at all except in the Arctic where the Coppermine Series might be regarded as a very small example. To suggest (Shepard, 1948, p. 159 and 173) that the Atlantic and Gulf Coast shelves have only a veneer of young sediments over older is to contradict the evidence from deep wells quoted by Murray. To maintain that no similar Precambrian and Paleozoic shelves ever existed is to deny the existence of an average rate of erosion which was only a fraction of that of to-day.

It seems quite untenable to suggest that there was so little erosion before Mesozoic time. It is also quite unnecessary because Kay (1948) and Eardley (1947 and 1949) have pointed out that the Appalachian and Cordilleran Mountains were formed out of precisely such shelves as are now forming on the Gulf and Atlantic Coasts. This seems to be an entirely satisfactory explanation. The Jurassic age of the oldest rocks known in these shelves suggests that they only started to form after the Appalachians had been built. Lawson (1942) has even suggested that the process will soon be repeated on the Gulf coast. On the Pacific coast there has not yet been time to form a shelf since the Cordillera was built.

This suggests that the mechanism of growth is already known and indeed it is widely accepted for recent time, but it is often coupled with the idea that there was throughout Precambrian time a continental block, formed in some other undefined manner. Perhaps this idea is widely held because even after the idea had been accepted that continents are growing it was felt necessary to have a pre-existing block to supply the sediments by which growth proceeds. But is that so? A shelf must be formed only by erosion, but once failure has occurred volcanism supplies abundant lava, ash and intrusive rocks from the interior of the earth to add to the continent. Rubey (1950) has suggested that during the earth's history "conceivably the hydrosphere and atmosphere may have come almost entirely from the earth's interior'. Could not the continental material have done so also?

Rate of Volcanic Extrusion

The surface of the continental blocks is approximately 50,000,000 square miles and they are about 20 miles thick. If the earth is somewhat over 3 billion years old (Holmes, 1949) then all that is required in order to build the continents is that an average of one-third of a cubic mile of new sialic rock should have been extruded each year.

It would be difficult if not impossible to estimate precisely the rate at which such contributions have been made, but it will perhaps suffice to show that the known contributions are such as to make the rate appear to be a reasonable one.

There are three kinds of igneous rock which are known to be quantitatively the most important. These are granites, andesites and basalts. They will be discussed in turn.

The rate and method by which granite is formed cannot be observed in recent rocks as it takes place at depth. Much granite and more granite gneiss has been formed in the past and it is increasingly abundant in the older rocks. But it is doubtful how much of the contributions of granite should be included in this calculation. Admittedly, in areas of young rocks like the United States and central Europe there is evidence of the intrusion of granite magma, but its source is a matter of debate. If it came from the depths as granite the answer to our problem is easy, but erosion should expose more granite in the older rocks. A cursory examination of maps of old areas suggests that this is the case, but it is not. The old shield areas are not composed of granite, but of well foliated granite gneiss showing abundant evidence of containing great amounts of metamorphosed sediments as has been maintained by geologists in every shield area. The disappearance of the shelves rather than indeterminate petrological arguments force one to believe that the roots of mountains are formed of sediments to which only small additions of materials have been made. These additions have chiefly been water and heat which are supplied during primary mountain building along the great arcuate fractures from the depths. The contributions of new continental material in the granites and gneisses may thus be largely illusory and will not be included, but to take the opposite view would enlarge the source of continental material.

The rocks which are added along the island areas are predominantly andesites, dacites and latites so that they have an average composition similar to granodiorite. At present there are about 500 volcanoes listed as active. To form one-third cubic mile of new rock each year each volcano would have to emit a sheet of lava a square mile in area and about 4 feet thick. Probably most volcanoes do not contribute this much each year, but the most active like Paricutin extrude much more. Fenner (1923) has estimated that the tuff in the Katmai Valley of Ten Thousand Smokes is more than one cubic mile in volume and represents one principle sandflow. That would equal the contribution necessary from the whole world for three years and it is not the largest single eruption known.

Turning to basalts and pyroxene andesites the quantities known to have been formed are very great. Von Tillo estimated that 2,000,000 square miles on continents and islands were covered by 'young' (Tertiary?) volcanic masses (Daly, 1933, p. 138). Great volumes have been formed under the oceans, for examples 500,000 cubic miles in the Hawaiian Islands alone (Zimmerman, 1951). Of course, oceanic erruptions contribute nothing to continents to-day, but the continents may include rocks poured out in the ocean. Lawson (1932) has argued that the action of sea water is breaking down basalt leaves a more siliceous residue which would be of sialic composition.

These figures do not establish the rate of volcanic out-pouring, and it is not known whether adequate data to establish that rate exists, but they perhaps suffice to show that the formation of continents by extrusion of volcanic rocks and to a greater or less extent by the intrusion of plutonic rocks is a reasonable proportion. Naturally, most of the rocks now exposed have been reworked through succeeding cycles of erosion, deposition and metamorphism so that they are no longer in their original form.

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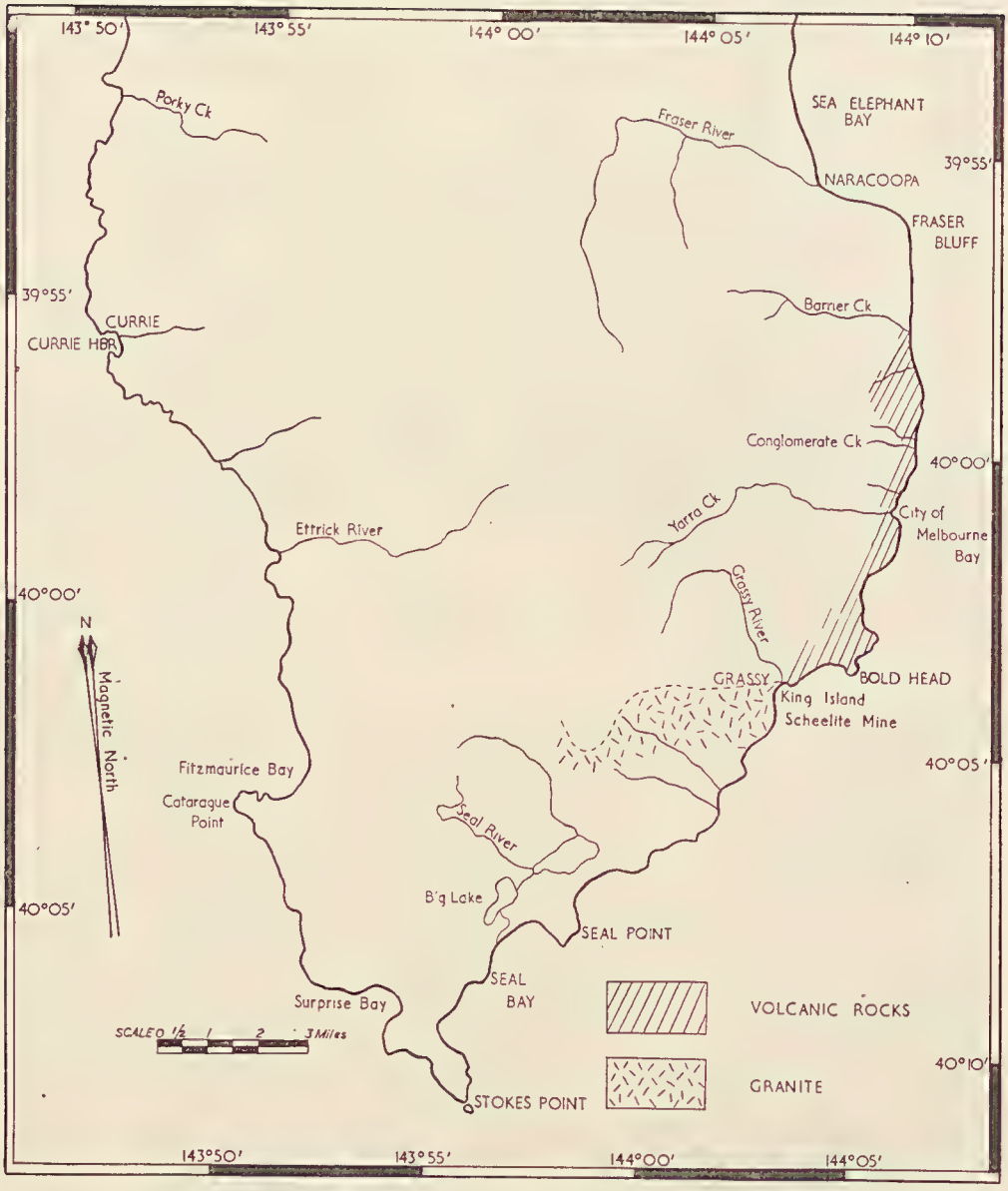
Fig. 1.



Southern portion of King Island showing the locality of the Volcanic Suite.

Pap. & Proc. Roy. Soc. Tasmania, 1950 (15th December, 1951)

The Petrology of the Volcanic Rocks of South East King Island, Tasmania

By

Beryl Scott

WITH 6 PLATES AND 2 TEXT FIGURES

Abstract

Spilites and picrite basalts in the form of massive, pahoehoe, aa and pillow lavas comprise the greater part of a volcanic suite, presumed to be Middle Cambrian in age, which outcrops along the south eastern coast of King Island, Bass Strait, Tasmania, Australia. In the spilites the augite is unusually fresh and in the associated breccia fragments of undevitrified volcanic glass still exist. It has been suggested that some of the albite may be primary because of its ophitic relation and intergrowth with the augite. The results of both late magmatic and post magmatic alteration have produced an interesting assemblage of minerals including hydrogrossular which has not been described before in a similar context.

Introduction

The suite of volcanic rocks under consideration crops out along the south-east coast of King Island, Bass Strait, Australia. It extends for a distance of about 8 miles from Barrier Creek in the north to Grassy (latitude 40° 3′ S, longitude 144° 4′ E) in the south where it is probably terminated by a fault along the Grassy River.

The rocks dip about 40° to the east and strike approximately N. 10° E. Here and there they have been dislocated by small faults, striking usually about 290°-300°, which have prevented relatively accurate determination of the thickness of them. However, it is estimated that the volcanic suite has a greater thickness than 1000 feet.

The volcanic rocks are associated with tillite and varve. The greater part of the suite overlies these glacials but some of the basal members underlie them or are even interbedded with the varves.

Scattered over the island are outcrops of granite which seem to indicate that the whole island is underlain by this rock type. At Grassy the volcanic rocks have most probably been intruded by granite but unfortunately the contact has been concealed because of faulting and a recent covering of sand dunes.

Age

In 1910 Debenham noted the occurrence of basalt south of the Fraser River and basic tuff at City of Melbourne Bay but ascribed a Tertiary age to them and correlated them with the Tertiary eruptives of Western Victoria. Then in 1915, Waterhouse recorded a brief description of an intensely altered series of basic and acid igneous rocks and igneous breccias and tuffs along the south-east coast of the island. He classed them tentatively as Cambro-Ordovician in age because of their similarity to the porphyroids on the West Coast of Tasmania. Because of the associated tillite and dolomitized varve, Carey (1946) correlated the series with the Zeehan glacials and Montana melaphyre volcanics of Tasmania and assigned them to the Pieman Group of rocks of Upper Proterozoic to Cambrian (?)

in age. At Dundas Trilobites, determined by Öpik* to be Upper Middle Cambrian in age, have been found in rocks interbedded with the Curtin Davis lavas reputed to be similar to those at Zeehan. West of Zeehan Trilobites, Brachiopods and Cystoids have been found in 'keratophyre tuffs' which overlie the Montana melaphyres and glacials. These fossils indicate an upper Middle Cambrian age for these rocks in this area. If the King Island volcanics are equivalent to those at Zeehan then their age may be stated as Upper Middle Cambrian.

However, the age of these volcanic rocks still remains a moot problem. No fossils have been found in the underlying sediments. If the age of the glacial beds is late Pre-Cambrian or very early Cambrian or even Upper Middle Cambrian then the volcanics are as old because they are so intimately related.

Although the presence of glass in the tuffs would seem to indicate a much younger age, the suite is definitely older than the granite, by which the rocks are affected, and this granite is most probably of lower Palaeozoic age.

Mode of Occurrence and Rock Types

In the field these volcanic rocks are quite striking and in spite of the great age which has been imposed upon them appear to be unusually fresh, so much so that they look as if they could have just issued from a volcano. This fact is well illustrated by the photographs in Plates I and II.

The forms of flow taken by the lavas are massive, one example showing columnar structure, aa or block, pahoehoe or ropy, and pillow. As well there is an accompanying group of fragmental rocks. Here and there narrow dykes intrude the suite. Generally speaking, the field form serves as a rough kind of classification for the rock types. Each form seems to have its own rock type with its particular kind of crystallization and mineral constituents. These will be described below.

The sequence of types overlying the glacials appears to be breccia and massive lava followed by aa, pahoehoe, and pillow, the resulting rock being in accordance with the prevailing conditions at the time of eruption. Showers of tuff were probably ejected throughout the period of vulcanicity.

Massive Lavas

These are normal flows of lava of varying thicknesses and seem to be the basal lavas of the series. Massive lavas occur below the glacial beds, interbedded with the varves and immediately overlying the glacials.

The rock is a spilite in composition and either appears as a normal looking basalt or a basaltic type with an extremely ophitic texture.

The type resembling a typical basalt (see Plate IV, figure 3) consists of laths of plagioclase and small grains of augite and magnetite. The plagioclase is almost pure albite, $Ab_{98}An_2$, and in parts shows alteration to chlorite and kaolin. The augite is surrounded by borders of a brown coloured mineral, otherwise it is relatively fresh. In some sections where the augite grains are larger, zoning and incipient hour-glass structure are present. Chlorite is abundant and appears in the interspaces of the plagioclase laths and augite granules. A little epidote in the form of small grains and patches of calcite, varying in abundance are also present. Sometimes small circular vesicles are present and these have been filled with chlorite and epidote.

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* Personal communication from Mr. M. R. Banks, palaeontologist, Geology Department, University of Tasmania who accompanied Dr. A. A. Öpik of the Bureau of Mineral Resources, Geology and Geophysics, Canberra, Australian Capital Territory, in the field. Stratigraphy from unpublished work of J. N. W. Elliston.

A coarser phase, doleritic in texture, but mineralogically the same, exists. Ilmenite is found surrounding patches of analcite. An interesting feature about this rock is that it shows evidence of slight metamorphism in the clouding of the felspar. Tiny needles of tremolite are found extending along the edges of the plagioclase crystals at right angles to the edges and pointing inwards.

The other type of massive lava is the one consisting of large plates of augite which are pierced by small laths of plagioclase. The augite is colourless, has good cleavage and is extremely fresh except for alteration to a brown mineral around the edges. The birefringence is ·030. The mineral is biaxial positive with an optic axial angle of 51° and an extinction angle of 40°. These properties indicate a diopsidic variety. Some of the large plates of augite have been so broken up by the presence of the plagioclase that they appear to consist of numerous small augite grains and it is not until the mineral is observed under analysed light that it is realized the mineral plate is homogeneous. This ophitic fabric is depicted in Plate V, Fig. 3. The plagioclase is albite and has been altered to sericite and contains patches of minute brown granules of hydrogrossular. Also present in the groundmass are granules of brown sphene, epidote, quartz, and calcite.

Another phase of this type of basalt gives rise to an unusual and interesting rock. Microscopically the rock consists for the most part of two minerals, diopsidic augite and a felspar which has been mostly pseudomorphed by sericite and some chlorite, although small patches of the unaltered albite remain. As usual the diopside is quite fresh and has similar properties as described above. Cleavage is strong and continuous and in some sections two at 90° are seen. The augite forms homogeneous plates which are broken only by the presence of the plagioclase.

The amazing feature of the rock is that the diopside and albite form perfect intergrowths covering the whole field of the microscope. (See Plate V, Figs. 1 and 2.) Occasionally between the areas of graphic intergrowth is to be found epidote. The author is unaware of a description of a similar phenomenon in the geological literature read.

Two questions are raised by the occurrence of such an intergrowth. First, is the structure an exsolution structure or secondly is it a true eutectic? The possibility of an exsolution structure can be neglected because the whole mass of rock is composed of such a structure and apparently is a feature of primary crystallization, probably formed at a later stage in crystallization following the formation of the ophitic fabric. This primary crystallization structure is the answer to the second possibility, that is a eutectic structure, and will be discussed in some detail later.

Pillow Lavas

These lavas have the typical ellipsoidal form of pillow lavas. The pillows vary from one to six feet in diameter. Each has a chilled margin of about half to one inch thick before a zone of radially arranged elongated vesicles filled with chlorite and other secondary minerals. Towards the centre the pillows show variolitic structure. Sometimes the material around the varioles has been weathered away leaving the varioles to stand out like marbles while at other times the varioles and surrounding material have weathered evenly, in which case the varioles are distinguished by their lighter colour. Examples of both types of weathering of varioles are shown in the photographs, Figs. 3 and 4 on Plate I. In some instances the surface of the pillow has a ropy structure.

The type of rock present is photographed in Plate IV, Fig. 4. It consists of a few idiomorphic laths of plagiclase up to 1 mm. in length and a few subidiomorphic phenocrysts of fresh augite in a groundmass of feathery augite and plagioclase and some granules of epidote and magnetite. The plagioclase is albite some

of which shows no or only simple twinning. Some of the larger crystals show alteration in part to chlorite. Small vesicles lined with epidote and filled with chlorite are present. Other vesicles, lined with chlorite and/or epidote, are filled with quartz. The rock is traversed by very fine veins of secondary minerals, epidote, quartz, and calcite.

Pahoehoe (ropy) lavas

This lava type is found in irregular flows varying from 6 to 18 inches in thickness, each having a chilled surface and base. See Plate II, Figs. 3 and 4.) The surface of some flows reveals beautifully preserved ropy structure as illustrated in Fig. 3, Plate III. In the field some of the pahoehoe type of lava appears to be so contorted that it grades into the pillow type of lava. The chilled margin is about one inch in thickness and grades into a zone very rich in vesicles and then in some cases to a region of variolitic structure.

The crystallization of the pahoehoe lava varies from the surface of the flow towards the centre. The top section is very fine grained and contains minute crystals of augite and plagioclase with a few phenocrysts of olivine, now pseudomorphed by chlorite. Vesicles are very abundant and are mostly elongated more or less parallel to the top of the flow and average about 1·5 to 2 mm. in length. In some specimens the vesicles are circular or oval in shape, filled with chlorite and are so numerous that the name 'bile bean rock' has been given. This vesicular and fine grained type passes downwards into a type where vesicles are less numerous and olivine pseudomorphs are wanting. The augite and plagioclase have increased in size. The plagioclase is lath shaped and the augite is arranged in sheaf-like masses of radiating crystals. (See Fig. 2, Plate IV.) Most pahoehoe types fall into this general description but the alteration in some has been different.

In some, the vesicles have been filled by chlorite and epidote and in others by calcite, prehnite or albite. In most cases the plagioclase is albite and shows alteration to chlorite and hydrogrossular while the augite, on the other hand, has remained relatively fresh. Prehnite and sericite, albite, quartz, chlorite, epidote and hydrogarnet are to be found in the vesicles and interspaces in the coarser grained parts. It seems as though in the various pahoehoe lavas that either chlorite is the predominant infilling mineral when hydrogarnet is more abundant or prehnite when hydrogarnet is less abundant. Sometimes where the quartz has come in contact with the augite fine needles of tremolite, pointing into the quartz, are developed about the augite. Also there is a concentration of iron in the pyroxene along the tips of the crystals. Amongst the pahoehoe lavas is an excellent example of granules of hydrogrossular replacing olivine. (Plate VI, Fig. 3.) In some specimens some of the augite has been replaced by numerous tiny granules of pale green chlorite.

Aa (block) Lavas

These seem to merge from and into the pahoehoe and pillow lavas. Stray pillows, budding into each other by means of necks, as illustrated in Plate II, Fig. 1, are found amongst the block lavas. The blocks are irregularly shaped and vary in size, an average size being 4 to 5 inches. The surfaces are often irregular, shiny and iron stained. In general the block lava is a porphyritic rock consisting of phenocrysts of olivine, now pseudomorphed by almost colourless chlorite, in a very fine grained greyish coloured groundmass. (See Plate IV, Fig. 1.) The phenocrysts vary in size up to 1·3 mm. and in some cases are grouped together to give the rock a glomeroporphyritic texture. The crystals, on the whole, are idiomorphic and it was by the crystal outline and apical angle that the original

mineral was determined to be olivine as there is no trace of the original mineral remaining. The form of the chlorite which is pseudomorphing the olivine is in aggregates of fibrolamellar structure. Its refractive indices were determined to be $\alpha = 1{\cdot}591$, $\gamma = 1{\cdot}594$. The mineral is biaxial positive and length slow. X-ray powder photography verified that it is of the pennine variety with the three strongest interplanar spacings being 7·146, 3·558 and 4·736. Pointing inwards from the sides of the chlorite and arranged haphazardly in the phenocrysts are needles of colourless to very pale green tremolite, ranging up to ·25 mm. in length. Some of the phenocrysts show patchy alteration to brown hydrogrossular. As illustrated by Fig. 4 on Plate VI. In other cases, however, the hydrogrossular has completely pseudomorphed the olivine crystals. In some sections it appears as if some pyroxene phenocrysts were present as well as olivine. These have been completely pseudomorphed by chlorite but definite cleavage traces still remain.

The groundmass is very fine grained, in some specimens probably devitrified glass, and is blotchy grey in colour. Under high power it is found to consist of fibrous needles of colourless tremolite and tiny patches showing incipient crystallization of pyroxene, most probably pigeonite. An attempt was made by X-ray powder photography to determine the type of pyroxene but many difficulties were encountered because of the nature of the mineral, its extremely fine crystallinity and its relationship with tremolite. However, a photograph was taken of the powdered groundmass and after elimination of the tremolite lines, the identity of the remaining mineral was determined as a clinopyroxene, possibly pigeonite. Because of its form the pyroxene gives anomalous optical properties. For the most part, the crystals are length slow, although some are length fast. It is optically positive with a rather small optic axial angle. After much difficulty the refractive indices were determined as $\alpha = 1{\cdot}629$ and $\gamma = 1{\cdot}653$ but the correctness of these cannot be vouched for due to the impossibility of separating the pyroxene from the tremolite. Persistent fringes of tremolite adhered to the pyroxene. Extinction appeared to be straight but again this may be due to the nature of the crystals.

In the groundmass and occasionally in the phenocrysts are to be found very small cubic crystals of the brown spinel, picotite.

Occasionally vesicles are found and these are filled with chlorite or hydrogrossular. When the latter mineral fills the vesicles it is darker towards the edge and very pale brown towards the centre as seen in Fig. 4 of Plate VI. The refractive index increases from the edge towards the centre.

Perhaps the 'shower droplet' rock could be described under this heading, not because it could be classed as a block lava but because it too is a picrite basalt as above. This 'shower droplet rock' occurs in a bed of about 2 feet thickness. It resembles a bed of conglomerate especially on a weathered surface but closer examination of a non-weathered section reveals a certain amount of welding together of the lapilli. Two photographs, Figs. 1 and 2, of this rock appear on Plate III. Apparently this rock type has developed close to the vent of the volcano and is the result of the accumulation of small drops of lava or lapilli which have dropped one on top of the other when almost, though not completely, solidified. Only one example has been found and it occurs just north of the outcrop of tillite north of Conglomerate Creek. Microscopically it contains idiomorphic phenocrysts of olivine pseudomophed by chlorite and brownish green coloured iddingsite along the cracks and around the edges. A few small oval shaped vesicles filled with chlorite, some of which is radiating, are present. The groundmass is so finely crystalline that it is impossible to distinguish the mineral constituents. Small crystals of picotite are present. Between the small lapilli of lava which average half an inch in diameter is to be found colourless to very pale green pleochroic chlorite.

Fragmental Rocks

Breccia and tuff are found interbedded with the lavas and also between some of the pillows where they are banded and are very tough. In keeping with the lavas they are green in colour.

Generally the breccia consists of fragments of glass which is light brown or green in colour. The fragments are often irregularly cracked and some have been altered to colourless chlorite or a very dark green fibrous variety, possibly garnierite, the nickel bearing chlorite. The presence of nickel is not surprising because tiny flakes of pale, copper pink coloured niccolite were found in varved shale on the southern headland of City of Melbourne Bay. Epidote crystals and granules are usually present and are abundant along cracks and boundaries of the glass fragments. In many cases the glass has been altered to dark brown hydrogrossular, the alteration usually commencing around the edges and proceeding inwards until the whole fragment has been altered as depicted in Plate VI, Figs. 1 and 2. Other pieces of the glass show complete devitrification to fine grained rock or in another case the glass seems to pass over to quartz crystals. In some of these glassy breccias a few pseudomorphs of chlorite and hydrogarnet after olivine are present, also some crystals of picotite.

The presence of glass in this volcanic suite is an unexpected feature because of its age and its resistance to hydrothermal solutions. Specimens have been found in which the glass is very dark green in colour, highly vitreous, and shows conchoidal fracture like obsidian. Its refractive index was determined as 1·6927 and its specific gravity as 2·49. The chemical composition of this glass will be discussed later.

The tuffs between the pillows and other banded tuffs are very fine grained and appear to consist of tiny fragmental grains of quartz, felspar and epidote and contain patches of calcite and chlorite.

Dyke Rocks

The volcanic suite is traversed by numerous small dykes which seem to trend roughly in a north south direction at right angles to the fault pattern. In all cases they are only about 2 to 3 feet wide and from a few yards to 100 yards at the most in length.

Petrographically, for the most part, the rock type is much the same as in the volcanic suite, particularly the massive basaltic variety. In some cases large phenocrysts of plagioclase, now kaolinised and sericitized are present. The rock in one dyke has been altered to an epidosite consisting of epidote, quartz and chlorite. Veins of idiomorphic to subidiomorphic crystals of epidote and quartz containing needles of tremolite are present.

There is one exception to the general rock type and this is an olivine minette. The rock contains large phenocrysts of brown biotite showing strong pleochroism and cleavage and colourless olivine and augite surrounded by reaction rims of what appears to be a pyroxene. This reaction rim in turn is surrounded by a halo of small magnetite granules. The augite is distinguished from the olivine by its strong cleavage. The groundmass is holocrystalline and contains abundant light brown biotite showing strong pleochroism and birefringence. Crystals of a mineral, most probably a pyroxene, judging from the crystallographic outline, are replaced by light green chlorite surrounded by magnetite granules. Orthoclase is abundant but is slightly altered to kaolin and has taken on a brownish colour. Magnetite as well as forming haloes about the altered minerals is scattered throughout the groundmass. Needles of tremolite and apatite are abundant, also small grains of calcite. Only one dyke of this rock was found and it trended in a similar

direction to the fault pattern. Mineralogically this rock is a misfit in the spilitic suite. Minettes, according to Johannsen (1931) are usually associated with rocks of the granite-syenite family. As the volcanic series is intruded by granite in parts and closely underlain by it in others, it is most probably that this dyke rock is related to the granite rather than the volcanic rocks. A later age than the volcanics, that is, post faulting, is indicated by the direction of the trend of the dyke.

Chemical Composition

According to the chemical analyses of the rocks there are two groups, a picrite basalt with a composition comparable with the intra Pacific or Oceanic type and a spilitic type.

Generally speaking the picrite basalts are those found in the pahoehoe and aa lavas and the spilites in the massive and pillow lavas.

In Table I the analysis of the picrite basalt is given and for comparison the average analyses of picrite basalt of Hawaii (Daly, 1933, p. 397) and oceanite of the world (Tyrrell, 1926, p. 131).

TABLE I.—ANALYSES OF PICRITE BASALTS

	I.	(*a*)	(*b*)
SiO_2	46·53	46·62	45·6
Al_2O_3	10·51	8·68	8·3
Fe_2O_3	·62	2·04	2·3
FeO	8·27	10·52	10·2
MgO	17·36	20·86	21·7
CaO	10·04	7·15	7·5
Na_2O	1·90	1·41	1·3
K_2O	·22	·28	·4
H_2O+	3·71		
H_2O-	·31	·23	·6
TiO_2	·21	1·71	1·7
P_2O_5	Tr.	·14	·3
Cr_2O_3	....	·12	....
MnO	·16	·14	·1
NiO	....	·10	....
Total	99·84	100·00	100·00
Norm			
Orthoclase	1·11		
Albite	16·24		
Anorthite	19·46		
Diopside	24·20		
Hypersthene	·33		
Olivine	33·02		
Magnetite	·93		
Ilmenite	·46		
Apatite	....		
Water	4·02		

I.—Picrite basalt (aa lava), King Island, Tasmania, Anal. B. Scott.
(*a*) Average picrite basalt of Hawaii according to Daly (1933) p. 397.
(*b*) Average oceanite of the world according to Tyrrell (1926) p. 131.

The spilitic types have been plotted on a triangular diagram (Fig. 2) on the basis of Na_2O, FeO and MgO (Sundius, 1930) and each of these rocks falls well within the area of spilites. The picrite basalt on the other hand falls well outside the area and on the true basalt side towards the base FeO, MgO of the diagram.

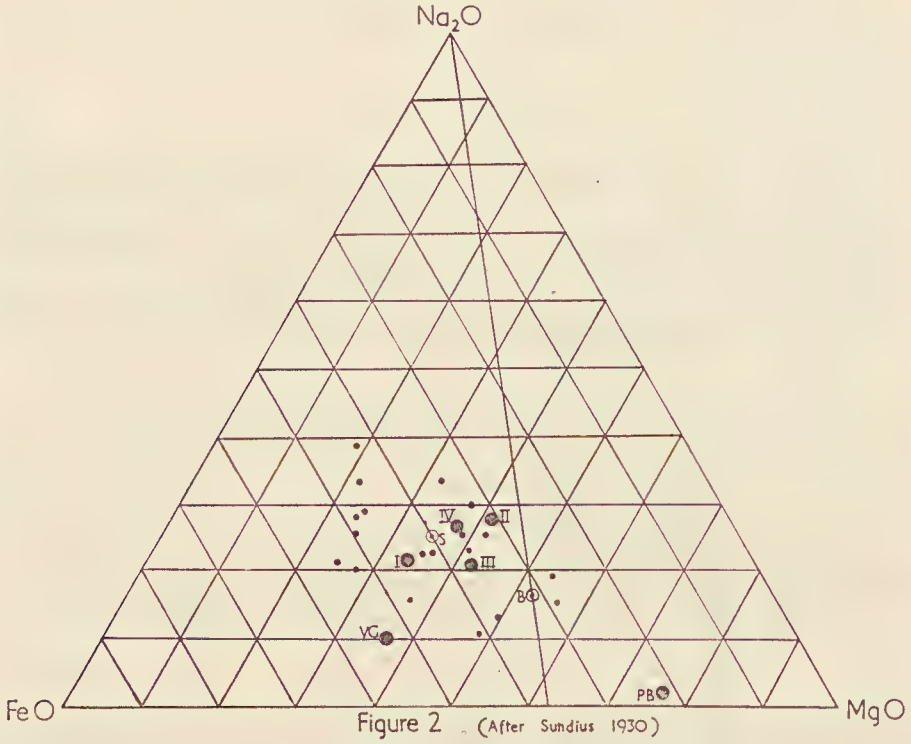

Figure 2 (After Sundius 1930)

- Spilites from various localities in the world as plotted on Sundius' original diagram
- S Average Spilite
- I-IV King Island Spilites
- PB Picrite Basalt King Island
- VG Volcanic Glass King Island
- B Average Basalt

Four spilites were analysed and the results of the analyses are tabulated for comparison with those of a British spilite, an average spilite and two of Benson's (1915) in which the augite is also very fresh.

A glance at the analyses would indicate that the series is very rich in alumina, a fact which is illustrated again when the alteration of minerals is considered. The possible source of this alumina is discussed later. Low titanium is a feature of the rocks but nevertheless it is constant in the series. High potash in spilites I and II is probably due to the abundant sericitization of the felspar.

The analysis of the volcanic glass yielded an interesting result. It was hoped that the analysis showing the chemical composition of the glass would help to identify the nature of a parent magma of these lavas especially indicating whether it is a sodic or non sodic variety and at the same time to establish the fact as to whether the albite is primary or secondary. Contrary to expectation the glass is poor in the alkalis and magnesia but rich in lime and alumina for its silica content. Its position on the triangular diagram does at least indicate spilitic affinities. However, its composition does facilitate the explanation of some of the hydrothermal alteration. Perhaps the fact that this glass is so rich in lime helps to explain the stability of such an ancient glass.

TABLE II.—ANALYSES OF SPILITES

	I.	II.	III.	IV.	(*a*)	(*b*)	(*c*)	(*d*)
SiO_2	47·40	48·24	50·01	52·61	51·31	51·22	48·22	51·19
Al_2O_3	19·19	17·55	15·38	13·03	12·67	13·66	14·82	14·40
Fe_2O_3	1·48	1·05	4·86	3·90	·54	2·84	·56	4·43
FeO	8·26	7·04	9·21	8·48	7·99	9·20	9·25	9·04
MgO	3·60	5·27	5·85	5·10	2·19	4·55	5·58	4·51
CaO	11·25	10·43	6·35	7·26	8·17	6·89	8·81	6·05
Na_2O	3·40	5·58	4·77	5·60	5·21	4·93	4·95	4·18
K_2O	1·31	·97	·40	·42	·54	·75	·44	·78
H_2O+	3·32	2·88	2·60	1·65	·04	1·88	2·54	1·82
H_2O-	·34	·17	·23	·10	2·31		·15	·24
TiO_2	·29	·70	·73	·72	1·92	3·32	2·68	2·69
MnO	·13	·12	·21	·19	·45	·25	·23	·21
P_2O_5	n.dt.	·10	·09	Tr.	·90	·29	·24	·40
CO_2	....	·11	·13	·05	6·15	·94	1·40	abs.
S	....	....	....	·08	....	....	....	...
FeS_2	....	....	....	....	·30	....	·37	·19
Fe_7S_8	....	....	....	....	·17	...	....	...
NiO	....	....	....	....	....	....	·03	—
Total	99·97	100·21	100·82	99·19	100·86	100·72	100·26	100·13
Norms								
Orthoclase	7·78	6·12	2·22	2·22				
Albite	18·34	19·65	40·35	46·63				
Anorthite	33·08	20·02	19·46	10·01				
Nepheline	5·68	14·91	....	·28				
Diopside	19·15	24·76	8·96	21·99				
Hypersthene	....	....	7·20	....				
Olivine	19·05	7·74	11·18	9·76				
Magnetite	2·09	1·62	6·96	5·57				
Ilmenite	·61	1·37	1·37	1·37				
Pyrite	....	....	....	·04				
Apatite	....	·34	·34	....				
Calcite	....	·20	·20	·30				
Water	3·66	3·05	2·83	1·75				

I. Spilite (Intergrowth type), King Island, Tasmania, Anal. B. Scott.
II. Spilite (Ophitic type), King Island, Tasmania, Anal. B. Scott.
III. Spilite (Basaltic type), King Island, Tasmania, Anal. B. Scott.
IV. Spilite (Pillow lava), King Island, Tasmania, Anal. B. Scott.
(*a*) Spilite, West side of Tayvallish Peninsula, Argyllshire. Anal. D. G. Radley (Dewey & Flett (1911))
(*b*) Average spilite according to Sundius (1930), p. 9.
(*c*) Spilite Frenchman's Spur, Nundle, N.S.W., Benson (1915), p. 139.
(*d*) Quartz dolerite, Munro's Ck., N.S.W., Benson (1915) p. 139.

TABLE III.—ANALYSES OF VOLCANIC GLASS

	I.	(a)
SiO_2	44·14	47·57
Al_2O_3	15·63	14·85
Fe_2O_3	5·45	4·52
FeO	·93	8·28
MgO	2·75	7·33
CaO	20·44	8·99
Na_2O	·80	3·93
K_2O	·21	1·03
H_2O+	6·04	1·70
TiO_2	·31	1·61
MnO	·11	....
P_2O_5	n.dt.	·28
Total	100·81	100·09
Norm.		
Quartz	16·50	
Orthoclase	1·11	
Albite	6·81	
Anorthite	38·36	
Diopside	17·62	
Wollastonite	7·08	
Ilmenite	·61	
Magnetite	7·89	
Water	6·04	

I. Glass from breccia, King Island, Tasmania, Anal. B. Scott.
(a) Average analysis of 5 basaltic glasses from Washington (1917).

Identification of the fine grained tuff between the pillows was difficult microscopically because of the fineness of grainsize. However, chemical analysis has revealed that the rock is definitely a tuff of similar composition to its parent lavas and is not a banded chert, rich in silica, as one may be inclined to think because of its extreme toughness, hardness and field position.

$Si0_2$	51·14
Al_2O_3	9·01
Fe_2O_3	2·32
FeO	3·99
MgO	12·49
CaO	14·34
Na_2O	1·67
K_2O	·39
H_2O+	2·64
$H_2O—$	·20
TiO_2	·49
MnO	·16
P_2O_5	ndt.
CO_2	·13
Total:	99·74

Tuff, Between Pillows of Lava, King Island, Tasmania, Anal. B. Scott.

Trace Elements

Spectrographic analyses for trace elements were carried out on several of the analysed rock specimens in the Department of Mineralogy and Petrology, University of Cambridge.

The results of these spectrographic analyses have been combined with the corresponding analyses and are tabulated in Table IV.

The amounts of each trace element are fairly constant in the volcanic suite and in keeping with the basicity of the rocks. They compare favourably with those in other rocks.

Chromium and nickel are low in the basaltic pillow lava varieties of spilites while copper is high in the pillow lava. Barium is highest in the ophitic type of spilite. The absence of tin is surprising. Has this tin been removed by hydrothermal solutions or was it originally absent?

TABLE IV.—TRACE ELEMENTS IN KING ISLAND ROCKS (Expressed in parts per million)

	I.	II.	III.	IV.	V.	(a)	(b)	(c)
SO_3	....	....	....	....	....	1,200	....	....
P_2O_5	....	1,000	900	....	....	2,400	700	2,800
SiO_2	465,300	482,400	500,100	526,100	511,400	485,000	504,200	482,400
Al_2O_3	105,100	175,500	153,800	130,300	90,100	130,100	165,500	178,800
Ga_2O_3	*(<6)	*13*	*20*	*13*	*20*	*30*	*30*	*10*
Cr_2O_3	*804*	*329*	*29*	*44*	*659*	*2,000*	*600*	*500*
TiO_2	2,100	7,000	7,300	7,200	4,900	10,300	8,400	9,700
V_2O_3	*115*	*257*	*257*	*404*	*110*	*500*	*450*	....
Fe_2O_3	6,200	10,500	48,600	39,000	23,200	14,300	5,200	31,600
Li_2O	*43*	*258*	*108*	*22*	*108*	*40*	*10*	*20*
MgO	173,600	52,700	58,500	51,000	124,900	129,100	73,100	75.000
NiO	*573*	*127*	*38*	*89*	*255*	*250*	*100*	*200*
CoO	*57*	*32*	*46*	*46*	*32*	*90*	*35*	*100*
CuO	*69*	*75*	*313*	(>*313*)	*31*	*200*	*200*	....
FeC	82,700	70,400	92,100	84,800	39,900	91,700	96,100	59,500
ZnO	....	....	....	....	....	*60*	*70*	....
Sc_2O_3	*30*	*54*	*54*	*54*	*23*	*30*	*15*	*30*
ZrO_2	*	*20*	*40*	*40*	*27*	....	....	....
MnO	1,600	1,200	2,100	1,900	1,600	1,900	700	1,300
Na_2O	19,000	55,800	47,700	56,000	....	20,300	15,600	25,500
Yt_2O_3	*(<*13*)	*19*	*25*	*38*	*(<*13*)	....	....	*3*
CaO	100,400	104,300	63,500	72,600	143,400	95,200	123,200	109,900
ThO_2	....	....	....	....	....	*30*	*60*	....
La_2O_3	*	*	*	*	*	....	....	....
SnO	*	*	*	*	*	*200*	*350*	*200*
PbO	*	*	*	*	*	....	....	....
K_2O	2,200	9,700	4,000	4,200	....	4,500	1,900	8,900
BaC	*(<*5*)	*558*	*56*	*5*	*112*	*80*	*200*	*70*
Rb_2O	*(<*10*)	*109*	*(<*10*)	*(<*10*)	*(<*10*)	*20*	*20*	*20*

I. Picrite basalt, King Isand.
II. Spiite (ophitic type), King Isand.
III. Spilite (basaltic type), King Island.
IV. Spilite (pillow lava), King Island.
V. Banded tuff, from between pillows, King Island.
(a) Olivine basalt, centre of dyke, Poortji (Frankel, 1942 p. 18).
(b) Dolerite, Kohstaol type, Execution Rock Sill (Walker and Poldervaart, 1949 p. 286).
(c) Average gabbro, according to Wager and Mitchell, 1943, p. 286.
Roman type—determined by chemical analyses.
Italics—determined spectrographically.
....—not recorded.
*—present below sensitivity limit.

Hydrothermal Alteration

This particular section of the study of the petrology of these lavas is the most interesting, not only because it introduces an extremely interesting assemblage of minerals but because the origin of the solutions responsible for the changes is controversial.

Before proceeding to describe the types of alteration it would be advisable to define the term 'hydrothermal' as used by the author as nomenclature in this field is rather confusing and conflicting. In this paper the term is used in the same sense as used by Shand (1944) when he proposed that high temperature hydrothermal be the stage between 700°-300° C and low temperature hydrothermal below 300° C and the term to be all embrasive in that it includes the effects of late magmatic alteration or alteration by extraneous solutions.

Hydrogrossular—a New Occurrence

Several occurrences of garnets associated with rocks of basic and ultrabasic intrusions have been recorded. Hutton (1943) pointed out that the mineral described as grossularite in the rodingites of New Zealand is not a true calcium garnet but one of the hydrogarnets belonging to the isomorphous series, tricalcium aluminate hexahydrate—grossularite. Yoder (1950), in his recent investigation on the stability of grossularite, suspects that the majority of naturally occurring garnets described as grossularite contain some hydroxyl groups. He is of the opinion that the dry end member of the grossularite—$Ca_3Al_2(OH)_{12}$ series does exist but that it cannot exist in the presence of water at elevated temperature.

Occurrence:—Hitherto a similar type of occurrence of hydrogrossular has not been described. As mentioned above, all examples have been from intrusive rocks. However, in 1910 Fenner described the occurrence of garnet as a secondary mineral in the Watchung basalt where it has been derived from olivine, felspar and diopside. Fenner writes 'This mineral has not heretofore been recognised under exactly similar circumstances, so far as the writer is aware'. This description appeared before the existence of a hydrogarnet series was established but no doubt if the garnets were studied in light of recent information it would prove to be a member of the grossularite—$Ca_3Al_2(OH)_{12}$ series.

In these basic volcanic rocks under consideration the hydrogrossular is definitely secondary. As previously mentioned it is found to be pseudomorphing almost perfect idiomorphic phenocrysts of olivine (see Plate VI, Fig. 3) and in some cases the plagioclase. It is also found in veins and vesicles (see Plate VI, Fig. 4). A great proportion of the glass in the breccias has been converted to hydrogarnet. Some pseudomorphs of chlorite after olivine show the presence of hydrogrossular along cracks and/or in a patchy fashion towards the centre. The hydrogarnet replacing the olivine and plagioclase is in the form of tiny granules and not one large crystal. In the vesicles and veins it has a concretionary form and the various members of the hydrogarnet series can be recognized by the differently coloured concentric layers and varying refractive indices. In some rocks the hydrothermal solution containing this mineral has attacked the groundmass, thus converting it into hydrogarnet, as illustrated in Fig. 4 on Plate VI. This hydrogarnet is more abundant in the picrite basalts than the spilites but in the latter some of the augite shows alteration around the edges to a brown coloured material. There is a possibility that this material may be one of the early phases during the garnetising process.

Properties:—The Hydrogrossular varies from dark brown to very pale brown or almost colourless.

The refractive index also varies from 1·663 to 1·753 according to the water content. It is interesting to note that in the vesicles the refractive index of the various layers increases from the edge inwards, commencing with a rather hydrous layer with low refractive index and grading into an almost anhydrous member of the series.

For the most part, the mineral is isotropic but some sections show very low birefringence.

Chemical Composition:—Owing to the nature of the mineral it was impossible to separate the various members of the series present so a chemical analysis was made on an average powder.

For comparison several other analyses have been tabulated in Table V.

TABLE V.—ANALYSES OF HYDROGROSSULAR

	I.	(*a*)	(*b*)	(*c*)	(*d*)
SiO_2	37·28	34·48	37·60	36·05	38·8
Al_2O_3	23·11	19·87	22·15	25·79	22·66
Fe_2O_3	5·26	0·61	·50	nil	1·75
FeO	0·73	0·85	·55	·56	....
MgO	4·12	2·07	tr.	·15	·68
CaO	27·44	37·40	38·40	35·72	35·00
Na_2O	....	0·02	tr.	·13	....
K_2O	....	0·01	tr.		....
H_2O+	1·37	4·65	1·20	1·10	....
H_2O-	0·44	0·23	·20	....	....
TiO_2	0·06	0·03	·10	·03	....
MnO	n.dt.	·02	tr.	·15	·30
Cr_2O_3	n.dt.	n.dt.	·10	....	....
Total	99·81	100·24	100·95	99·68	99·19

I. Hydrogrossular, King Island, Tasmania, Anal. B. Scott.
(*a*) Hydrogrossular, Champion Ck., Waimea, New Zealand, Anal. F. T. Seelye, (Hutton, 1943, p. 74).
(*b*) Green "Jade"; Buffelsfontein, Anal. H. G. Weall (Hall, 1924, p. 48).
(*c*) Grossularite, Roding River, Dun Mt., New Zealand, Anal. Dominion Lab. (Grange, 1927, p. 165).
(*d*) Green Grossularite, Dana's System of Mineralogy.

An interpretation of the analysis of the King Island hydrogarnet showing the amounts of the various garnet molecules is given below.

Andradite	16·81
Tricalcium aluminate hexahydrate	4·73
Grossular	53·22
Almandine	1·83
Pyrope	13·97
Silica	3·38
Corundum	4·91

The chemical composition based on the general formula $X_3Y_2(ZO_4)_3\text{-}m(OH)_4m$ (McConnell, 1942), of this particular hydrogarnet has been determined as $(CaMgFe')_{2.631}\ (AlFe'''Ti)_{2.068}\ ((Si,Al)O_4)_{2.833}\ (OH)_{.667}$.

The valency of the formula was balanced by taking into consideration that $(OH)^{-1}$ replaces $(O)^{-2}$ of the SiO_4, leaving empty spaces.

In this case it was necessary to allot some alumina to the ZO_4 group where it occupied the empty spaces. Alderman (1935) pointed out that this was also necessary in his case when dealing with almandine garnets.

TABLE VI.—CALCULATION OF FORMULA OF HYDROGROSSULAR

Oxides	Weight %	Molecular Proportions	Ionic Ratios	Positive Ions
SiO_2	37·28	·621	·621	2·761
Al_2O_3	23·11	·226	·452	2·010
Fe_2O_3	5·26	·033	·066	·293
FeO	·73	·010	·010	·044
MgO	4·12	·103	·103	·458
CaO	27·44	·490	·490	2·179
H_2O+	1·37	·075	·150	·667
TiO_2	·06	·001	·001	·004

Ca	2·179		Al	1·771		Si	2·761	OH	·667
Mg	·458	2·681	Fe'''	·293	2·068	Al	·239 3·000	O	11·333 12·000
Fe''	·044		Ti	·004					

Valency balance:

Excess positive		Deficit positive	
$(OH)^{-1}$ in place of $(O)^{-2}$	·677	Al^{+3} in place of Si^{+4}	·239
Ti^{+4} in trivalent group	·004	Empty divalent spaces 2(3·000—2·681)	·638
Excess trivalent group	·068		
Total	·875		·877

According to Flint, McMurdie and Wells (1941) silica can replace water in both $3CaO,Al_2O_3,6H_2O$ and $3CaO,Fe_2O_3,6H_2O$ so that the end products become grossularite and andradite respectively. Chemically 6 molecules of H_2O are interchangeable with 3 molecules of SiO_2. The replacement, from a structural point of view, was explained by McConnell (1950) when in dealing with the crystal chemistry of montmorillonite, he likened the replacement of silica by water to the similar case of the hydrogarnets. He demonstrated that $(OH)_4$ has a stable configuration as discrete tetrahedra and 4H becomes equivalent electrostatically to Si in the structure.

X-Ray Data:—An X-ray powder photograph of the hydrogrossular was taken on a 9 cm. Unicam camera, using copper radiation and a nickel screen. X-ray data are given in Table VII.

Albite

Albite appears in these rocks as a complete replacement of a more basic plagioclase and in vesicles where it is associated with chlorite and has a pink colour in hand specimen.

Its refractive index is less than Canada Balsam and in the sections belonging to the zone normal to the 010 face the maximum extinction angle is $18\frac{1}{2}°$ indicating a composition of $Ab_{98}An_2$, almost pure albite. Sometimes the albite shows well defined lamellar twinning but at others it is untwinned. When untwinned in the vesicles it is difficult to distinguish it from quartz, the only means of distinction often being by the biaxial positive figure of albite as opposed to the uniaxial positive one of quartz. Often the albite shows secondary alteration to sericite, kaolin and chlorite.

TABLE VII.—INTERPLANAR SPACINGS OF HYDROGROSSULAR FROM KING ISLAND

h k l	d	Intensity	θ in degrees
110	7·195	*	6·151
220	4·303	*	10·321
222	3·572	*	12·462
400	3·026	****	14·761
420	2·689	****	16·600
332	2·563	**	17·504
422	2·460	***	18·265
431; 510	2·361	**	19·058
521	2·200	**	20·517
532	1·951	**	23·276
620	1·908	*	23·894
444	1·735	*	26·384
640	1·672	***	27·462
642	1·607	****	28·667
732; 651	1·539	*	30·062
800	1·503	**	30·855
840	1·344	**	34·994
842	1·313	**	35·945
664	1·283	*	36·944
864	1·116	**	43·667
10,4,2	1·110	**	44·603
880	1·063	*	46·506
10,71; 10,55	·978	**	52·055
12,60; 10,84	·897	*	59·302
14,40; 12,66	·826	*	68·958
14,42; 12,66 10,10,4	·818	*	70·386

****=very strong; ***=strong; **=weak; *=very weak.

Strangest lines d=2·689, 1·607, 3·026.

Calculation of the size of the unit cell using the formula $a=\frac{\sqrt{h^2+k^2+l^2}\lambda}{2 \sin \theta}$ was determined to be 12·031A° when $\theta = 68{\cdot}958°$ and 12·030A° when $\theta = 70{\cdot}386°$. The unit cell size of 12·03 for this hydrogarnet lies within the range 11·84A° for grossularite to 12·56A° for tricalcic aluminate hexahydrate given by Flint, McMurdie and Wells (1941).

As mentioned in the petrographical description of the rock types albite is found as an intergrowth and the ophitically arranged with fresh diopsidic augite. It may well be, under such circumstances, that the albite is primary and not secondary but this point will be discussed later. The fact remains that some, if not all, of the albite is definitely secondary.

Chlorite

Chlorite, perhaps, is the most common of the secondary minerals. It occurs in all the rocks, where it is found to replace or partly replace olivine, augite and plagioclase and to occupy vesicles and veins.

The chlorite varies from a colourless to rather dark green variety. Even in the same vesicle there has been known to be two different varieties. X-ray powder photography has shown that the chlorites do vary. The chlorite pseudomorphing olivine is generally of the colourless variety while that in the vesicles is of various shades of green. The most common variety is pennine.

The form of the chlorite pseudomorphing the olivine is in aggregates of fibrolamellar structure. It has a low birefringence of ·003 and the interference colours range from black and grey to anomalous colours. The refractive indices are $\alpha = 1{\cdot}591$, $\gamma = 1{\cdot}594$. The mineral is optically positive and is length slow. According to X-ray photography the three strongest interplanar spacings are

d = 7·146, 3·558, 4·736. The green chlorite common in the vesicles is pleochroic. It, too, is optically positive and shows interference colours grading from grey to anomalous blue. Its refractive indices are higher than those of the colourless variety and are $\alpha = 1{\cdot}624$, $\gamma = 1{\cdot}629$. Most probably this chlorite is a variety of pennine too.

Epidote

Like chlorite, epidote is rather abundant and usually occurs as small granules or idiomorphic crystals in vesicles and veins, often lining the vesicles for chlorite. It is colourless to pale green and is slightly pleochroic. In some cases it shows twinning. It is distinguished from the diopsidic augite by its straight extinction.

Tremolite

Tremolite is very common in the series and occurs in all types of lava, aa, pahoehoe, and the massive type. It is almost colourless to very pale green with low birefringence and a maximum extinction angle of 20°. It replaces plagioclase in the block lava and commonly replaces or partly replaces augite in the massive lava towards the granite contact at Grassy. In some of the pahoehoe lavas it occurs in a peculiar intergrowth fashion with augite where it may be partially replacing that mineral or even replacing plagioclase. There is no evidence on which to decide. In the block lava it is also associated with chlorite in pseudomorphing the olivine and in the vesicles.

Prehnite

Prehnite occurs in the vesicles of some of the pahoehoe and pillow lavas. In hand specimens it is generally white with a greenish tinge. It is often in radiating form and shows typical bow-tie structure. It is length slow and has a double refraction of about ·02.

Sericite

This mineral is fairly common as a replacement of albite. However, it is found, too, sometimes lining the vesicles for prehnite or occurs as flakes with the prehnite.

The presence of sericite in the latter context was unexpected. At first this flaky mineral in the vesicles was considered to be either talc or pyrophyllite, which have similar optical properties to muscovite, as the assemblage of minerals was more in keeping with either of these, plus the fact that alumina and magnesia bearing solutions had been at work. However, after much difficulty a tiny fragment was separated from the prehnite and this was treated as a powder fragment because of its fine flaky nature and an X-ray photograph was taken. Photographs taken on small diameter cameras failed to distinguish the mineral from either talc or pyrophyllite but the photograph taken on a 19 cm. Unicam camera, when the lines were more spaced, definitely indicated that the mineral is sericite.

Calcite

One would expect to find more of this mineral than is actually present. It is found, however, in vesicles and veins. It is possible that the temperature conditions were too high for its formation in abundance.

Quartz

Quartz, like calcite, is not over abundant. It is only found in vesicles and veins and in the epidosites at Grassy.

Discussion

An examination of the chemical analyses and the mineral assemblage of the rocks indicate a great richness in alumina. The following questions arise. What is the origin of this constituent? Was it derived from a rich aluminous magma and the alteration the result of percolating late stage magmatic solutions, or was it derived from an external source and therefore the alteration the result of the invasion of the solidified lavas by foreign solutions?

The late magmatic stage alteration can be supported. The following equations indicate that the present mineral constituents could have been derived from a lava in which there has been a rearrangement of constituents, once the 'spilitic reaction' had commenced, that is assuming that the plagioclase was a more basic variety originally.

Each type of lava will be considered and the supposed original constituents will be taken into consideration.

Pahoehoe lava

(*a*) in which chlorite is the predominant secondary mineral

Olivine
Basic plagioclase ——> Chlorite, Hydrogrossular / Albite, Chlorite, Hydrogrossular
Pyroxene
Anorthite
Albite

1. $2CaAl_2Si_2O_8 + Na_2O + 2SiO_2 \longrightarrow 2NaAlSi_3O_8 + 2CaO + Al_2O_3$
2. $CaAl_2Si_2O_8 + 2CaO + SiO_2 \longrightarrow Ca_3Al_2(SiO_4)_3$ (Grossular)
3. $3Mg_2SiO_4 + 4H_2O + Al_2O_3 \longrightarrow Mg_5Al(OH)_8(Al,Si)_4O_{10} + MgO$ (Chlorite)
4. $Mg_2SiO_4 + 3CaO + Al_2O_3 + 2SiO_2 \longrightarrow Ca_3Al_2(SiO_4)_3 + 2MgO$ (Grossular)
5. $CaAl_2Si_2O_8 + 5MgO + 4H_2O + SiO_2 \longrightarrow Mg_5Al(OH)_8(Al,Si)_4O_{10} + CaO$ (Chlorite)

(*b*) in which prehnite is the predominant secondary mineral

Basic plagioclase ——> Albite, Chlorite, Grossular / Chlorite, Pyroxene / Prehnite, Quartz in vesicles
Pyroxene

Equations 1, 2 and 5 as above.

$3CaO + Al_2O_3 + H_2O + 3SiO_2 \longrightarrow H_2Ca_2Al_2Si_3O_{12}$ (Prehnite)

Spilitic lavas (massive and pillow types)

Equations as for (*b*) except epidote formed more readily than prehnite.

$4CaO + 3Al_2O_3 + 6SiO_2 + H_2O \longrightarrow 2Ca_2Al_3(SiO_4)_3OH$ (Clinozoisite)

Aa lava

Olivine
Basic plagioclase ——> Chlorite, Hydrogrossular / Tremolite
Pyroxene
Pyroxene

$3Mg_2SiO_4 + 4H_2O + Al_2O_3 \longrightarrow Mg_5Al(OH)_8(Al,Si)_4O_{10} + MgO$ (Chlorite)
Olivine

$2CaAl_2Si_2O_8 + 3MgO + 4SiO_2 + H_2O \longrightarrow Ca_2(Mg,Al)_5(OH)_2(Si_4O_{11})_2 + Al_2O_3$ (Tremolite)
Anorthite

$3CaO + Al_2O_3 + 3SiO_2 \longrightarrow Ca_3Al_2(SiO_4)_3$ (Grossular)

The late magmatic theory, however, appears to break down when it is realised that the tuffs, too, have been subjected to a similar alteration process. Even the glass fragments which had been completely solidified so that no late stage solutions could have remained have succumbed in places to hydrothermal alteration. A close study of the analyses of the volcanic glass and hydrogrossular may give a clue to this problem.

TABLE VIII.—ANALYSES OF VOLCANIC GLASS AND HYDROGROSSULAR

	Volcanic Glass	Hydrogrossular (Altered glass)	Constituents gained during alteration
SiO_2	44·14	37·28	
Al_2O_3	15·63	23·11	X
Fe_2O_3	5·45	5·26	
FeO	4·93	·73	
MgO	2·75	4·12	X
CaO	20·44	27·44	X
Na_2O	·80	....	
K_2O	·21	....	
H_2O	6·04	1·81	
TiO_2	·31	·06	
MnO	·11	n.dt.	
Total	100·81	99·81	

Apparently this change involved an introduction of alumina, lime and magnesia. From this evidence it seems that the source of these constituents is external but where could this source be? In the introduction to this paper it was mentioned that the volcanic suite is intruded by granite at Grassy. This may be the answer to the question for not only do Nye and Knight (1943), in their report on the King Island scheelite mine at Grassy, report an introduction of alumina and lime in the interchanges of material during mineralization but the lavas apparently closer to the granite show a greater degree of hydrothermal alteration. Here the pyroxene of the lavas is practically wholly converted to tremolite. The plagioclase is albite and in some cases has been partially replaced by sericite, chlorite and hydrogarnet. Epidote and iron ore granules are abundant. Abundant veins and vesicles of pink albite and chlorite and sometimes quartz are very common and it is not unusual to find large patches of the lava converted to an epidosite, i.e., epidote, albite and quartz rock with abundant iron ore. The presence of tremolite would indicate that these lavas are not in the inner part of the contact aureole but in the outer, for according to Harker (1939) tremolite is not stable at high temperatures.

Further evidence to support the idea that constituents may have been gained from the granite is provided by the glacial tillite and varves. These rocks have been haematitized and dolomitized to a considerable extent. Sometimes the tillite is haematitized and the varves overlying it dolomitized. At other times most of the varves are haematitized as well and the dolomitization is not noticed. This is possibly due to the magnesia being lost to the overlying lavas and being incorporated in the formation of new minerals such as tremolite and chlorite. Unfortunately it has not been possible to trace the iron and magnesia rich zones consistently in the lavas because of the faulting which postdated the granite. Field evidence is consistent with the idea that a magnesia front is preceding an iron front. There is ample evidence of magnesia having been gained by the lavas but iron is not over abundant as evidenced by the formation of tremolite rather than actinolite and the almost colourless variety of chlorite. However, some perfect cubic crystals of iron pyrities are sometimes present in the lavas but these are often quite abundant in the dolomitized varves.

The temperature at which this hydrothermal alteration was achieved must be considered. The presence of such a hydrogarnet, containing a small amount of water, indicates that fairly high temperature hydrothermal conditions prevailed.

Yoder (1950), as a result of preliminary experimental work, tentatively states that members of the hydrogrossular series form in the presence of water at a temperature under approximately 750° C at atmospheric pressure and above 300° C, below which, according to field data, a different mineral assemblage, viz., calcite, quartz and zoisite, would be stable. Fenner (1910) states that in the Watchung basalt when the alteration was delayed until a rather late stage, the nodules of absorbed olivine passed over into chlorite, but in an earlier period, while the temperature was high, garnet was the chief mineral formed. He also points out that with an increase in prehnite, a mineral requiring a lower temperature for formation, in the rocks there is a decrease in garnet. This, too, has been noted in the King Island lavas as mentioned before. Apparently as the temperature fell below the range in which hydrogrossular was stable the excess lime and alumina were absorbed in the formation of prehnite, epidote, and other low temperature hydrothermal lime bearing minerals. The absence of zeolities and the relatively small amount of calcite and quartz for such an altered series are also indicative that the temperature conditions were higher than usual. In support of the late magmatic stage of alteration there is an apparent correlation of the amount of garnet with the degree of crystallization and hence fall in temperature. The fine grained porphyritic rocks such as the aa or fine grained phase of the pahoehoe lavas, which no doubt cooled rather rapidly, contain more hydrogarnet than the coarser grained pahoehoe and spilitic types which contain abundant prehnite.

The general conclusion to be drawn from the hydrothermal study is that if one considers all or some of the albite to be secondary, then both late magmatic reactions and reactions with solutions from external sources have played a part, the former as indicated by the spilitic reaction and the latter by the introduction of alumina. Lime and magnesia, which also play big parts, could have been derived from outside or from the magma itself during the late stage reactions. However, if one considers all the albite to be primary, then most of the alteration is post magmatic and probably due to the granite intrusion.

The Problem of the Pyroxene and its Bearing on the Origin of the Albite

An interesting feature of these lavas is the freshness of the pyroxene when the felspar has been albitized. Usually in spilitic rocks the ferromagnesian minerals are changed to chlorite and epidote but apparently not in this case.

Benson (1915) describes spilitic rocks, in which the augite is unusually fresh, from the Nundle District, New South Wales. He concludes that the albite may be primary in those particular rocks. In the King Island series under consideration there is further strong evidence to support the theory that the albite, or at least some of it, is primary because of its intergrowth and ophitic relation with the augite. The presence of ophitic fabric does indicate on the one hand that the albite may be primary, or on the other hand that it may be secondary, the result of sodic metasomation of normal basaltic rocks as indicated by Turner (1948) when discussing albite associated ophitically with fresh augite from rocks described by Benson from New South Wales and also by Eskola (1925) from Kendjarvi, Finland. However, in this suite the author feels that she can afford to be more assured and state that at least some of the albite is primary because of the eutectic between it and the diopsidic augite. The diagram by Bowen (1928) showing the crystallization of mixtures in the plagioclase field of the system albite-anorthite-diopside indicates that a eutectic does exist between diopside and albite, given the requisite conditions for formation. Although Bowen was concerned with an

anhydrous melt and the melt from which this rock was derived was no doubt hydrous it is unlikely that the relationship between albite and diopside would be appreciably affected.

It may happen that some of the albite is primary and crystallized out at an early stage and some late magmatic. Given the suitable conditions of composition of a sodic magma and the right temperature it is possible for the albite to be primary as shown by the eutectic. On the other hand, if temperature conditions are not suitable the magma may crystallize in the same fashion as a normal basaltic magma, leaving at the end a highly sodic fraction which would react with the more basic plagioclase, such as labradorite, to form albite.

Further confusion is added by the presence of beautifully fresh volcanic glass which seems to be too deficient in soda to indicate an original sodic magma from which primary albite could crystallize in spite of its position on Fig. 2, which indicates spilitic affinities.

Resistance of the pyroxene to alteration may be due to the fact that it was already in equilibrium with the surrounding mineral assemblage. Its optical properties determine it to be a diopsidic variety, therefore rich in lime and magnesia and possibly immune to further change by an infiltration of these constituents.

A Note on the Formations of the Lavas in the Field

Brief descriptions of the modes of occurrence of the volcanic series have been given earlier in the paper. The modes of occurrence, with the exception of the pillow lavas, suggest emission under subaerial conditions, the aa and pahoehoe forms and the columnar structure in one of the massive flows being the strong supporting factors.

No definite boundaries can be drawn between the pahoehoe, pillow and aa lavas as there are to be seen transitions from one to the other. In places the lavas are definitely of the pahoehoe, pillow or aa form but in others the pahoehoe seems to merge into the pillow and the aa lava appears to have formed by the breaking up, as it were, of the pillow and pahoehoe lavas. Sometimes the pillow-like structure has taken on a long twisted snake-like appearance about 18 inches in diameter, still with the cavity in the centre. The pahoehoe form appears at times to curl round and resemble the pillow form. Isolated pillows amongst block lava have a fractured appearance indicating that the blocks may possibly have been derived from pillows. This is illustrated by Fig. 1 on Plate II. These pillows often show excellent examples of bulbous budding. Noe Nygaard (1940) refers to floating basalt globes (30-60 cms. in diameter) amongst breccia which are now broken and occur as sector-like fragments or segments but these are the result of a stage during the subglacial intrusion of a magma.

The massive lava flows, on the other hand, are independent and are separated by beds of volcanic tuff and breccia. Breccia tuff and block lava appear between the pillows or interbedded with them. The so-called block lava in this case may be more in the nature of volcanic bombs. At times some of the pahoehoe forms seem to curl around small patches of breccia.

According to Washington (1923) aa and pahoehoe are the chief and most commonly occurring types of basaltic lavas and chemically there is no general difference in the composition of the two forms of lava. Both occur side by side and in the same flow in the Hawaiian Islands. Unfortunately, a chemical analysis of a pahoehoe lava was not attempted because of its amydaloidal nature and the zonal arrangement of crystallization. It would have been interesting to have seen the relationship between FeO and Fe_2O_3 for according to Washington the proportion of FeO to Fe_2O_3 is uniformly higher in the pahoehoe form than in the aa.

The aa form is supposed to be uniformly more crystalline than the pahoehoe which is highly vitreous. However, in the King Island rocks the reverse is the case. The aa lava has given rise to a very fine grained rock, some of which was probably glassy, containing phenocrysts which were originally olivine. Vesicles are wanting. The rock resulting from the pahoehoe lava, on the other hand, is very crystalline, the degree of crystallinity increasing from the surface towards the centre. The pahoehoe rock, mineralogically, seems to bridge the gap between the picrite basalt (aa lava) and the spilite (pillow lava). The pillow lavas sometimes resembles more the picrite basalt, especially when it is found amongst the block lava, and at other times seems to represent the finely crystalline pahoehoe rock. From observation in the field the author is inclined to think that the pillow lavas, generally, are varieties of the pahoehoe lavas and have formed under slightly different conditions of cooling. Possibly the pahoehoe lava has flowed into a local body of fairly shallow water thus facilitating a more rapid cooling and chilling process resulting in the formation of the pillows. As the pillows accumulated to the depths of the water the lava took on again the pahoehoe form.

According to Washington (1923) Day and Shepherd regard the pahoehoe lava as the high temperature form containing much gas and cooling quickly throughout because of the rapid expansion and elimination of the gas.

Although the vulcanicity was closely associated with glacial conditions the extrusions were probably not of the subglacial type as described by Noe Nygaard in 1940, these subaerial lavas having been emitted during an ice recession. There is evidence to show that volcanic action commenced before glaciation ceased in that flows of lava are found interbedded with varves. Also in other places the lavas are irregularly mixed up with the varves, suggesting that the lava was emitted through unconsolidated sediments.

The presence of glass fragments in the breccia towards the base of the volcanic series is again suggestive of conditions suitable for rapid chilling of the magma. Most probably the molten fragments were hurled into the melting ice, thus becoming rapidly solidified to glass.

Above it was suggested that the pahoehoe lava may have flowed into local bodies of water to form the pillow structures. These local bodies of water may have been melted ice water. Association with the pillows are breccias also containing glass, now devitrified or altered for the most part.

Evidence that the centre of eruption was close at hand is provided by the presence of a bed, about 2 feet thick, of 'shower droplet' rock. This rock is described earlier in the paper and as mentioned it is probably the result of the accumulation of small lapilli of lava which have dropped one on top of the other when almost, though not completely, solidified.

Throughout the period of vulcanicity the outpourings of lava were interrupted at intermittent periods when the type of action became explosive and showers of ash and other fragmental material were ejected.

Summary

The volcanic rocks from south-east King Island provide yet another interesting occurrence of a spilitic suite in which the pyroxene is unusually fresh. This time the magma has solidified in the forms of massive, pahoehoe, aa and pillow lavas together with subsidiary amounts of fragmental rocks.

The most important points to be drawn from the study are as follows:—

1. Chemically the rocks may be grouped into spilites and picrite basalts.

2. The lavas themselves provide evidence in the form of ophitic fabric and intergrowth between albite and diopsidic augite that some at least of the albite is primary. However, it is possible for some of the albite to have been formed at a late magmatic stage from soda rich solutions remaining after the normal crystallization of a soda rich basaltic magma.
3. The fragmental rocks provide much confusion in revealing fragments of beautifully fresh glass which is poor in alkalies but very rich in lime. Nevertheless, it shows spilitic affinities when plotted on the triangular diagram, Na_2O, FeO, MgO of Sundius (1930).
4. This volcanic glass when altered appears to have gone mostly and quite readily to hydrogrossular, a fact which is not surprising when the chemical composition of both are compared.
5. Hydrothermal alteration is prevalent and has most probably been due to both late magmatic and post magmatic solutions, the latter being derived from a nearby granite intrusion.
6. The alteration has enriched the rocks in alumina, lime and magnesia and has produced an interesting assemblage of minerals—hydrogrossular (a new occurrence), albite, chlorite, epidote, prehnite, tremolite, calcite and quartz—indicating fairly high temperature hydrothermal conditions at the time of their formation.
7. The pyroxene, diopsidic augite, is unusually fresh and it has been suggested that it was probably in equilibrium with the surrounding mineral assemblage and therefore immune to further change by an infiltration of lime and magnesia in which it was already enriched.
8. The modes of occurrence of the volcanic rocks indicate that vulcanicity commenced before glacial action has ceased. The emission was subaerial and took place, for the most part, during a recession of the ice.
9. The formation of the breccia containing the glass is possibly due to the chilling action of melted ice water.
10. Transitions from pahoehoe to pillow and aa lavas and vice versa exist and the formation of pillow lavas may be the result of the pahoehoe lava flowing into local bodies of this water.

Acknowledgments

The greater part of this study was carried out during the academic year 1949-50 in the Department of Mineralogy and Petrology, University of Cambridge, while the author was the holder of a Rotary Foundation Fellowship.

The author wishes to acknowledge and express her grateful thanks for the kindness and hospitality given her, during her visits to the area, by Mr. and Mrs. J. Skipworth and family of City of Melbourne Bay, King Island. She is also indebted to Professor S. W. Carey of the Geology Department, University of Tasmania, for introducing her to the area and for his helpful suggestions and criticism while reading the manuscript.

To Mr. T. McMahon, of the Photographic Section of the University of Tasmania, the author is most grateful for his help and interest in taking the photomicrographs and arranging the plates in this paper.

Locality Index

Locality	Quadrangle	Latitude S	Longitude E
Barrier Creek	....	39°58′	144°08′
City of Melbourne Bay	S.E. King Is. 10	40°00′	144°03′
Conglomerate Creek	....	39°54′	144°08′
Dundas	Zeehan 50	41°53′	145°28′
Fraser River	Sea Elephant 6	39°54′	144°02′
Grassy	S. E. King Is. 10	40°03′	144°04′
Grassy River	S. E. King Is. 10	40°03′	144°04′
King Island	....	39°35′—40°16′	143°50′—145°17′
Montana	Zeehan 50	41°51′	145°17′
Nundle	....	31°27′	151°08′
Yarra Creek	S.E. King Is. 10	40°00′	144°03′
Zeehan	Zeehan 50	41°53′	145°21′

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DESCRIPTION OF PLATES

PLATE I.

FIG. 1.—A field of pillow lavas just south of City of Melbourne Bay.
FIG. 2.—Pillows of lava separated by banded tuff.
FIG. 3.—A pillow of lava showing the differential weathering of the central and marginal areas. Note how the varioles stand out like marbles.
FIG. 4.—Central portion of a pillow of lava showing even weathering, the varioles being distinguished by their lighter colour.

PLATE II.

FIG. 1.—A pillow of lava, showing bulbous budding, amongst the block lava illustrated in FIG. 2. Note the irreguar cracking of the pillow.
FIG. 2.—A field of block lava south of Barrier Creek.
FIG. 3.—A general view of the thin flows of pahoehoe lava showing the general dip of the volcanics.
FIG. 4.—A near view of an individual pahoehoe lava flow. Note the variolitic structure towards the centre.

PLATE III.

FIG. 1.—Weathered surface of the "shower droplet" rock showing the size and shape of the lapilli.
FIG. 2.—Unweathered surface of the same specimen. Note that some of the lapilli are welded together.
FIG. 3.—A specimen of portion of the surface of a pahoehoe lava flow showing ropy structure.
FIG. 4.—A specimen of breccia containing fragments of volcanic glass showing alteration to hydrogrossular indicated by the white bands. The white patches also indicate hydrogrossular replacement.

PLATE IV.

FIG. 1.—Picrite basalt similar to the specimen analyzed. Olivine phenocrysts are pseudomorphed by almost colourless chlorite which is pierced by needles of tremolite. The groundmass is cryptocrystalline and consists of pyroxene and tremolite. ×56.
FIG. 2.—Pahaehoe lava containing radiating augite and laths of albite which are partly replaced by chlorite and hydrogrossular. Albite is the material in the vesicles. ×56.
FIG. 3.—Spilite (basaltic type) showing laths of albite and intergranular augite. ×56.
FIG. 4.—Spilite (pillow lava type) showing radiating augite and albite with granules of magnetite between the tiny sheafs. Analysed specimen. ×56.

PLATE V.

FIG. 1.—Spilite (analyzed specimen) showing graphic intergrowth (eutectic) between diopsidic augite and albite which has been greatly replaced by sericite. The albite is at extinction. ×56.
FIG. 2.—Spilite showing intergrowth as above. The intergrowth has not developed in any definite crystallographic direction. ×56.
FIG. 3.—Spilite (ophitic type) showing albite laths penetrating diopsidic augite. Albite has been greatly replaced by sericite and is at extinction in this figure. Analysed specimen. ×56.

PLATE VI.

FIG. 1.—Volcanic breccia showing glass fragments replaced by chlorite and hydrogrossular towards the margins. ×56.
FIG. 2.—A large fragment of volcanic glass in breccia showing alteration to hydrogrossular, represented by the dark bands. ×56.
FIG. 3.—Portion of the chilled margin of a pahoehoe lava showing the occurrence of hydrogrossular (small dark spots) in vesicles associated with chlorite and pseudomorphing olivine. ×35.
FIG. 4.—Picrite basalt showing the occurrence of hydrogrossular in a large vescile and as a replacement of olivine and the groundmass where it is indicated by the dark patches. ×35.

The photomicrographs (FIGS. 3 and 4) were taken in the Department of Mineralogy and Petrology, University of Cambridge.

Figure 1

Figure 2

Figure 3

Figure 4

Figure 1

Figure 2

Figure 3

Figure 4

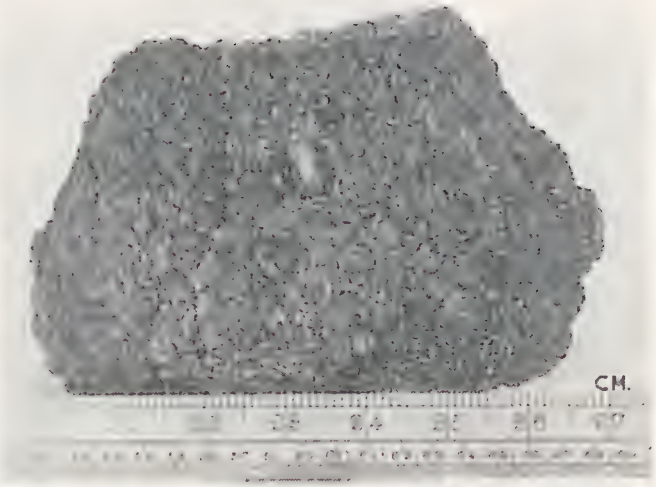

Figure 1

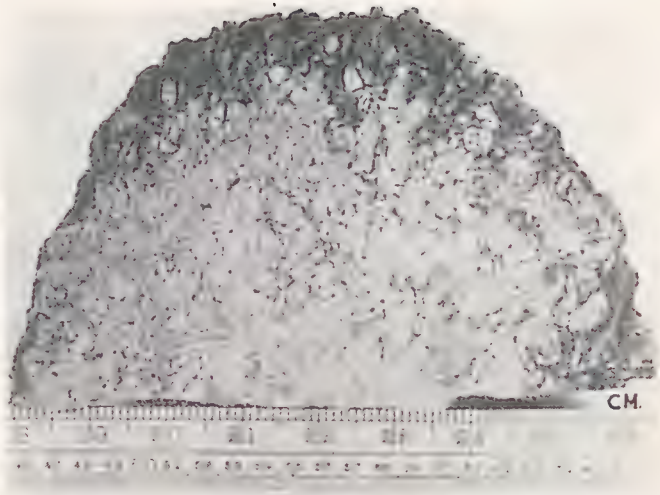

Figure 2

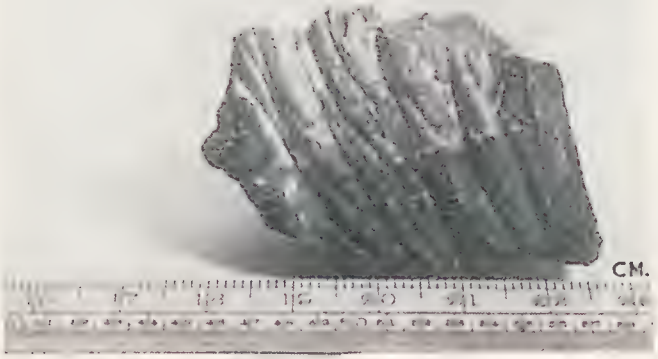

Figure 3

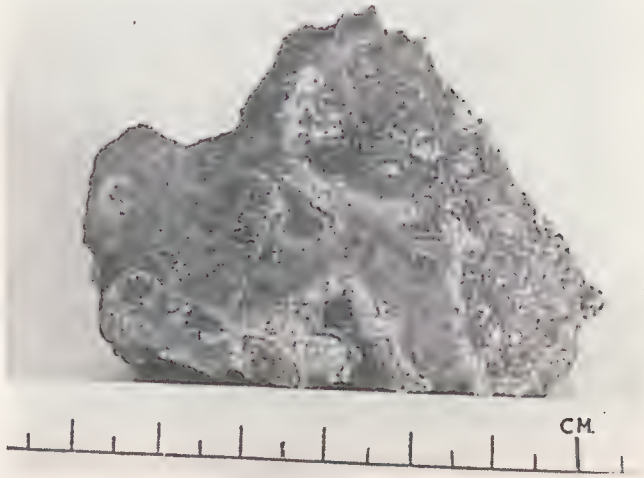

Figure 4

Figure 2 x56

Figure 4 x56

Figure 1 x56

Figure 3 x56

Figure 2 x56

Figure 4 x35

Figure 1 x56

Figure 3 x35

Figure 1
x56

Figure 2
x56

Figure 3
x56

The Female Urogenital System of Antechinus (Marsupialia).[1]

By

Joseph Pearson

and

John de Bavay

Tasmanian Museum

(With Two Plates)

Summary

An examination of the female urogenital system of *Antechinus* confirms the view that the sub-family Phascogalinae is the most generalized group of Australian marsupials. This system in *Antechinus* is as primitive as that of the members of the American super-family Didelphoidea and has many striking features.

General Account

The sub-family Phascogalinae which comprises the most primitive members of the super-family Dasyuroidea is composed of about half a dozen genera of which *Antechinus* may be regarded as a typical example. There are two Tasmanian species of this genus, *Antechinus swainsonii* (Waterhouse) which is also found in Victoria and New South Wales, and *Antechinus minimus* (Geoffrey) which occurs only in Tasmania and its associated islands.

Four specimens have been examined in the course of the present investigations, as follows:—

	D.C.L. Head and Body.
Antechinus swainsonii	
Tasmanian Museum, No. 269	135 mm.
National Museum, Melbourne, No. C886	150 mm.
National Museum, Melbourne, No. C890	135 mm.
Antechinus minimus	
Tasmanian Museum, No. 291	147 mm.

All the above specimens are fully grown adult females, though unfortunately it is not known which, if any, are parous.

Measurements. In these four specimens the antero-posterior length of the urogenital system, excluding the uteri, varies from 10·725 mm. to 25·25 mm. In the following table the antero-posterior lengths of the various parts are given in terms of μ as well as in percentages of the combined antero-posterior length of the vaginal complex and urogenital sinus *(af)*. Reference should be made to Fig. 1 in which are shown the various levels at which the measurements given

(1) The investigations dealt with in this paper were carried out at the Tasmanian Museum and were assisted by a grant provided equally by the Trustees of the Commonwealth Science and Industry Endowment Fund and by the Tasmanian State Government.

in the table are taken. These are:—*a*, anterior extremity of the vaginal system; *b*, anterior extremity of the culs-de-sac; *c*, posterior extremity of the culs-de-sac; *d*, anterior extremity of urethra (level at which the ureters, indicated in Fig. 1 by two crosses, enter the neck of the bladder); *e*, junction of the lateral vaginae (In *Antechinus* and most marsupials this also corresponds approximately to the opening of the urethra into the urogenital sinus. In the Potoroidae, however, in which the posterior sections of the lateral vaginae fuse to form the posterior vaginal sinus, the opening of the urethra is some distance caudal to the point of fusion of the lateral vaginae); *f*, level of clitoris (posterior extremity of urogenital sinus).

TABLE

Measurements of the Urogenital System of Antechinus

(in terms of μ and in percentages of the length *af*)

	af *Combined antero-posterior length of vagina and urogenital sinus*	**ae** *Antero-posterior length of vagina*	**ef** *Length of urogenital sinus*	**bc** *Length of cul-de-sac*	**ce** *Pseudo-vaginal gap*	**de** *Length of urethra*
No. 269	10,725μ	3,270μ 30%	7,455μ 70%	0,960μ 9%	1,800μ 17%	1,530μ 14%
No. C886 (1)	14,270μ	4,440μ 31%	9,830μ 69%	0,930μ 6·5%	2,670μ 18%	1,830μ 13%
No. C890	25,250μ	6,515μ 26%	18,735μ 74%	1,572μ 6·2%	2,440μ 10%	1,660μ 7%
No. 291	11,425μ	2,870μ 25%	8,555μ 75%	0,720μ 6·3%	1,500μ 13%	1,310μ 11%
Average	....	28%	72%	7%	14·5%	11%

(1) *af* and *ef* in C886 are only approximate as the posterior part of the urogenital sinus was not sectioned. This part, however, was measured as carefully as circumstances would permit.

As far as can be ascertained no adequate description of the female urogenital system of a Phascogale has been published hitherto, though Wood Jones (1949) recently discussed the general anatomy of a related form, *Dasycercus cristicauda* (Krefft), and gave a brief description of the female urogenital system of that species. The present account is given in some detail and forms part of a comprehensive study of the marsupial urogenital system which has been in progress for some years. Ultimately it is hoped to bring together in a single paper the salient features of the female urogenital system of the Marsupialia and to discuss from this angle the relationship of the five super-families of that Order.

Serial sections have been cut of all four specimens and the following description may be regarded to some extent as a composite one based upon an examination of the sections in the four specimens.

At a cursory glance the most noticeable features of the female urogenital system in the Phascogalinae are the relative insignificance of the vaginal region and the predominance of the uterine region and the urogenital sinus (see Fig. 1). These characters may be said to be common to all members of the Dasyuroidea.

Uterus (fig 1, *ut* and *ut.n.*). The uterine region has an antero-posterior length equal to about three-sevenths of the entire length of the urogenital system and is about equal to the length of the urogenital sinus. Each uterus is clearly divided into a fusiform uterine body *(ut.)* and a well-defined uterine neck *(ut.n)*. The Fallopian tubes lie in the normal position on the outer side of the anterior extremities of the uterine bodies. The right and left uterine bodies are slightly splayed and lie some distance apart but the two uterine necks after leaving the uterine bodies rapidly converge and for the more caudal part of their course run parallel to each other and in close contact, embedded in a common sheath of connective tissue. Thus the uterine necks present a characteristic Y-shaped appearance which, however, is not so marked as in the Dasyurinae. In three of the specimens examined the character is not so obvious since the two anterior converging arms of the Y are splayed and distorted so as to lie transversely or even to be reflected posteriorly, a condition probably caused by post-mortem pressure of the neighbouring abdominal organs. This distorted condition is somewhat similar to that shown by Wood Jones (1949) in his drawing of the right uterus of *Dasycercus cristicauda*.

In the case, however, of the Melbourne specimen No. C890, the Y-shaped appearance of the uterine necks is clearly shown (see Fig. 1), a condition which probably represents the normal disposition of the organs in the living animal and which is reminiscent of the Dasyurine arrangement. Each uterine neck opens into the proximal region of the vagina (cul-de-sac) near the free tip of a well-defined uterine papilla *(ut.p.)* which almost completely fills the cul-de-sac. This is shown in Fig. 2 except that the os uteri is made to open on the tip of the papilla, as it proved difficult to show the actual position of the opening and at the same time to preserve the essential features as clearly as was desired.

Vaginal Complex. The vaginal region comprises all that part of the genital system which lies distal to the uteri and which extends caudally as far as the anterior limit of the urogenital sinus. The vaginal system of each side may conveniently be divided into (*a*) a proximal region, the vaginal cul-de-sac *(m.v.c.)*; (*b*) an intermediate region, the anterior vaginal canal *(a.v.c.)*; and (*c*) a distal region, the lateral vagina *(l.v.)*.

Vaginal Culs-de-sac *(m.v.c.)*. These lie side by side immediately posterior to the two uterine necks with which they are connected, as indicated above. In all four specimens the right and left culs-de-sac are completely separate, but a good deal more material would need to be examined before it could be said with justification that this separation holds good throughout life. Unfortunately, it is not known whether any of the four specimens are parous, though some are fully grown and mature.

It is known from observations on other primitive forms, the members of the American super-family Didelphoidea for example, that the septum which separates the two culs-de-sac probably breaks down in some species at the first parturition and certainly does break down, whatever the cause may be, in mature specimens.

In the case under examination, however, the tissues separating the right and left culs-de-sac are so thick that it is not unlikely that the separation of the right and left culs-de-sac remains inviolate throughout life in the Phascogalinae.

It is interesting to record that each cul-de-sac is remarkably small and undeveloped, and varies in antero-posterior length from 720 μ to 1572 μ in the four specimens (see Table). Even this minute chamber is still further reduced as its cavity is almost entirely occupied by the uterine papilla *(ut.p.)*, and the condition of the culs-de-sac in the Phascogalinae is certainly as primitive as in any known marsupial.

Anterior Vaginal Canal *(a.v.c.)*. Each canal arises ventro-laterally from its cul-de-sac and sweeps forward and outward to the anterior limit of the vaginal bend where it passes imperceptibly into the lateral vagina. Actually there is no true morphological distinction between these two elements of the vaginal loop, and it might be claimed with justification that both elements are merely components of the lateral vagina. However, in *Perameles* Hill (1899) coined the term 'anterior vaginal canal' for a duct at each side which is probably homologous with the one now under discussion, and it is considered convenient to adopt Hill's designation for the proximal portion of the loop throughout the Marsupialia (see Pearson, 1950, p. 216). It is interesting to note, too, that the perameloid condition is also found in a somewhat modified form in the specialized Potoroidae, particularly in *Bettongia* (Pearson, 1950). In *Antechinus*, as might be expected in such a generalized form the vaginal complex follows the basic plan which is common to the less specialized marsupials.

Lateral Vaginae *(l.v.)*. This region of the vaginal system runs caudally and the right and left portions converge and fuse near their point of entry into the urogenital sinus. In nearly all members of the Dasyuridae examined in the course of these investigations there is a short caecal outgrowth arising from each lateral vagina. This has been found without exception in all specimens of the genera *Dasyurus*, *Sarcophilus* and *Thylacinus* which have been examined, but in the case of *Antechinus* only one of the four specimens so far examined, viz., C890, shows this condition.[1] It is not unlikely that this short caecum represents the last vestige of the Wolffian duct. The fate of this duct in female marsupials and the composition of the marsupial lateral vagina are matters of considerable interest which will be discussed in a subsequent paper.

Urogenital Sinus *(u.g.s.)*. As in the case of all members of the Dasyuroidea the length of the urogenital sinus is considerably greater than the antero-posterior length of the vaginal complex. It will be seen from the figures given in the table that in *Antechinus* the sinus is about two and a half times the antero-posterior length of the vagina. The relatively great length of the sinus in the two most primitive of the five marsupial super-families, viz., the Didelphoidea and the Dasyuroidea, indicates that this character may be regarded as a primitive feature.

Discussion

In the genus *Antechinus*, which is a typical member of the Phascogalinae, the female urogenital system has the following notable features:—

(1) The uteri have an antero-posterior length equal to that of the urogenital sinus. The right and left uterine necks form a Y which is, however, relatively much shorter than in the Dasyurinae.

[1] After this paper had gone to the press a fifth specimen of *Antechinus* was examined and showed no sign of the vestigial Wolffian duct. As in the other specimens the two culs-de-sac were completely separated.

(2) The vaginal complex is relatively small and its antero-posterior length is less than one-half that of the urogenital sinus.
(3) The vaginal culs-de-sac are extremely small and probably remain separate throughout life. The cavity of each cul-de-sac is almost entirely obliterated by the swollen uterine papilla.
(4) The pseudovaginal gap is equal to about one-half of the vaginal length.

The condition of the female urogenital system of the Dasyuroidea as a whole will be discussed in a paper which is now in course of preparation, but it may be said that the female urogenital system of the Phascogalinae is more primitive than that of the Dasyurinae. Nothing is known of the condition in mature members of the Thylacininae but an examination of young female specimens of *Thylacinus* indicates the probability that the female urogenital system of that genus is less primitive than that of *Antechinus*.

It is not proposed to discuss here the various interesting problems which are suggested by a morphological study of the primitive marsupials which are placed in the sub-family Phascogalinae. Such a study would naturally evoke speculations on the nature and character of the earliest marsupials which found their way into the Australian area. There is, too, the question whether this entry was made from the north or through a former land connexion with the Antarctic continent. Much emphasis has been placed upon the evolutionary specializations which have resulted from the isolation of a marsupial fauna within the Australian continent. But it is as well to be reminded that in the midst of this evolutionary activity certain groups have persisted more or less unaltered both in structure and habit and probably differ in no important respect from the first marsupial immigrants into the Australia area. The phascogales are a case in point and the evidence provided in the present paper shows that the female urogenital system of the Phascogalinae is as primitive as that found in any recent marsupials including even the American Didelphoidea.

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References to Figures

a.v.c.—Anterior vaginal canal.
bl.—Bladder.
f.t.—Fallopian tube.
l.a.v.c.—Left anterior vaginal canal.
l.m.v.c.—Left vaginal cul-de-sac.
l.ur.—Left ureter.
l.ut.n.—Left uterine neck.
l.ut.p.—Left uterine papilla.
l.v.—Lateral vagina.
m.v.c.—Median vaginal cul-de-sac.
ov.—Ovary.
r.l.v.—Right lateral vagina.
r.m.v.c.—Right vaginal cul-de-sac.
r.ur.—Right ureter.
r.ut.n.—Right uterine neck.
r.ut.p.—Right uterine papilla.
u.g.s.—Urogenital sinus.
ut.—Uterus.
ut.n.—Uterine neck.
ut.p.—Uterine papilla.

Description of Plate I

Fig. 1.—Diagram of the female urogenital system of *Antechinus*. × 10. (The letters (a)—(f) indicate the various levels at which the measurements given in Table I. were made).

Fig. 2.—Diagrammatic representation of right and left culs-de-sac. × 25. The left cul-de-sac is shown in horizontal section so as to expose the cavities of the uterine neck, cul-de-sac and anterior vaginal canal of the left side. (Note.—In Figs. 1 and 2, for the sake of simplicity, each os uteri is shown as though opening on the tip of the ureteric papilla. Actually it opens on the ventral side of the papilla slightly anterior to the tip.

Fig. 3.—Diagrammatic transverse section of the right cul-de-sac through AB (see Fig. 2). × 25.

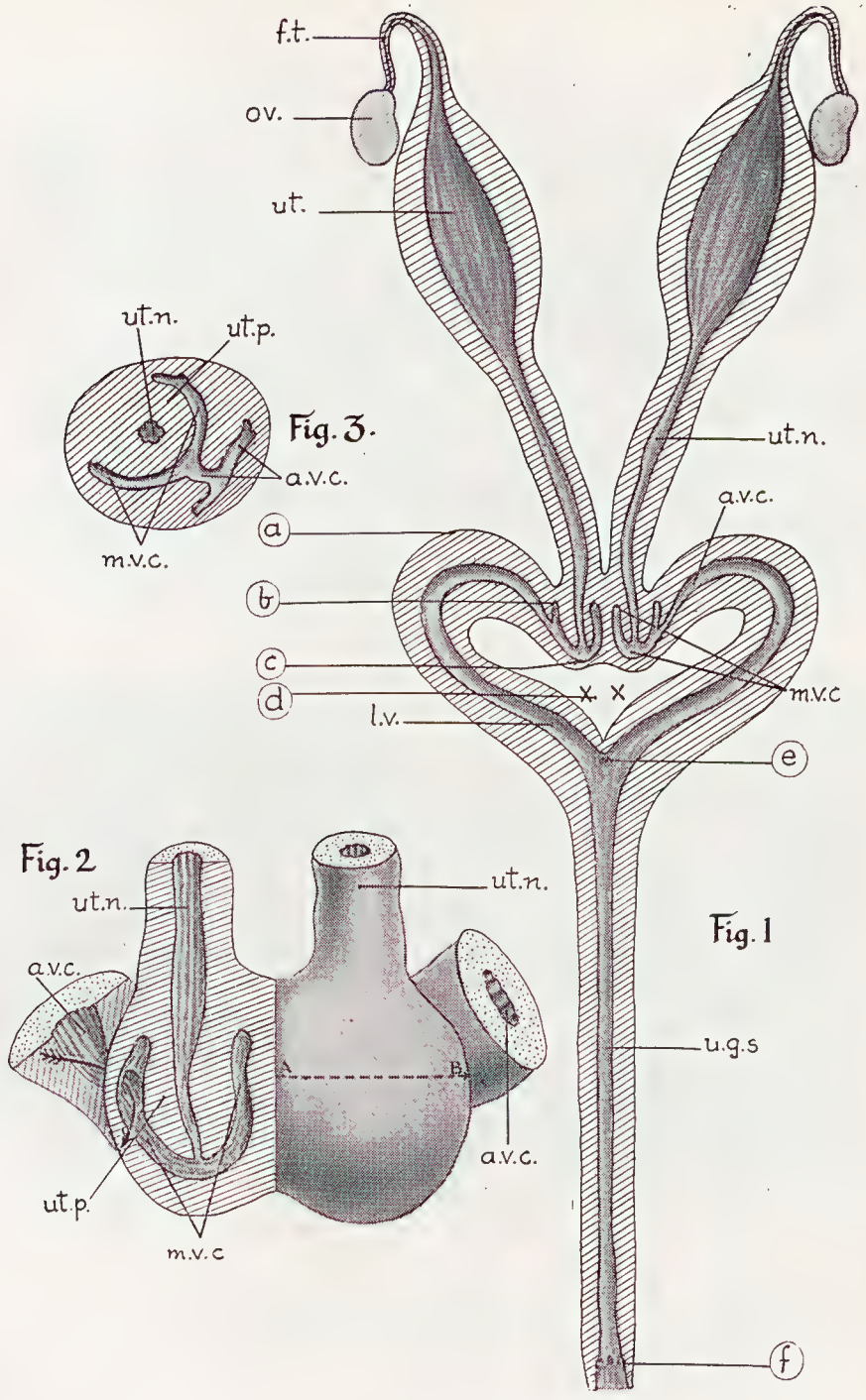
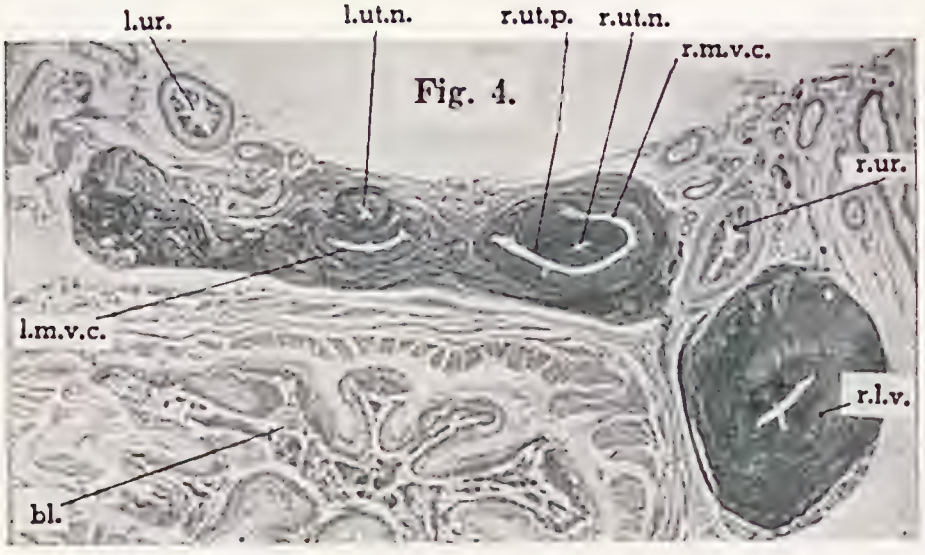


Fig. 3.

Fig. 1

Fig. 2

For references to figures see opposite page



Photomicrographs of transverse sections through region of vaginal cul-de-sac in *Antechinus minimus* (no.291) x 20. (The sections are cut slightly obliquely and are asymmetrical in consequence. Therefore the left lateral vagina is not shown).

FIG. 4.—*Slide 27, section 16.* The right uterine papilla almost completely fills the right cul-de-sac. Only the anterior portion of the left cul-de-sac is shown.

FIG. 5.—*Slide 28, section 11.* The posterior extremity of the right cul-de-sac is shown. The connexion of the left anterior vaginal canal with the left cul-de-sac is seen.

Notes on the Female Urogenital System of *Tarsipes spenserae* (Marsupialia).[1]

By

J. M. de Bavay

Tasmanian Museum

(With 9 Figures)

Summary

Two specimens of the female urogenital system of *Tarsipes spenserae* are described. One of these is parous, the other non-parous. In both examples the cul-de-sac is very long and in the parous specimen a patent connexion exists between it and the urogenital sinus. A patent connexion in the non-parous specimen is doubtful. The parous urogenital system displays a singular example of postponed regression of the Wolffian duct.

In 1900 the female urogenital system of *Tarsipes rostratus*(2) was described for the first time by Hill. Hill based his description upon two females, one parous and the other probably parous, both of which, had a permanent connexion between the cul-de-sac and the urogenital sinus. This represents a condition unique among the Phalangeridae and, with the exception of certain Macropods, among the Marsupialia generally. As this is a point of considerable significance it was decided to re-examine the question(3).

The information obtained in this way completely confirms Hill's observations and in some respects supplements them.

The literature on *Tarsipes* is meagre and apparently no full description of its structure exists. Described originally by Gray (1842) and almost simultaneously by Gervais and Verreaux (1842) *Tarsipes* has, despite its structural peculiarities, received little attention from comparative anatomists. However, sufficient is known to indicate that *Tarsipes* occupies a special position among the Phalangeridae, being in some ways the most specialized member of that family.

The snout is long and curved and, accordingly, well adapted to searching flowers for the pollen and nectar upon which it chiefly subsists. Its degenerate dentition, too, reflects a diet which needs little mastication, the cheek teeth being variable in number, haplodont in form and completely vestigial (Bensley, 1903). Parker (1890) noted several aberrant features in the skull and concluded 'in the general form of the skull . . . *Tarsipes* differs from all the other Phalangistidae'.

(1) The investigations dealt with in this paper have been assisted by a grant provided equally by the Trustees of the Commonwealth Science and Industry Endowment Fund and the Tasmanian State Government.

(2) The specific name *spenserae* is now considered to have priority over *rostratus*.

(3) This was made possible through the kindness of the Director of the National Museum, Melbourne.

In its pes, *Tarsipes* shows the greatest modifications of any of the Phalangeridae. Bensley (1903) says "the second and third digits being greatly reduced, and almost completely enclosed in a common integument; while the fourth digit is greatly enlarged, and like the fifth is provided with a nail instead of a claw, as in the placental Primates. In addition to these obviously progressive characters, *Tarsipes* presents other peculiarities. The terminal pad of the hallux is not swollen to the same extent as is usual in arboreal forms. The hallucal planter pad is short. The second digital plantar pad is subdivided and its outer portion has migrated to the fourth digit".

In its female urogenital system, too, *Tarsipes* would appear to differ from the other members of its family.

Two spirit specimens may years old provided the material for this investigation and have been numbered 316 and 317(4). Their measurements are as follows:—

	No. 316	*No. 317*
Head (snout to ear-notch)	27 mm.	24·5 mm.
Head (D.C.L.)[5]	37 mm.	36 mm.
Head and body (D.C.L.)	93 mm.	95 mm.
Tail	94 mm.	95 mm.
Ear	11 mm.	11 mm.
Pes	15 mm.	14·5 mm.

Unfortunately Hill does not give the measurements of his specimens so a comparison cannot be made.

The pouch of No. 316 is very definite and possesses four nipples, two of them very prominent; the other two are small and insignificant. This specimen is almost certainly parous. The pouch of No. 317 is scarcely discernible and the nipples quite indistinguishable. This specimen is quite definitely non-parous. These two females, then, nearly indentical in size differ in their sexual condition and this difference might be expected to be demonstrated in their respective reproductive systems.

Serial transverse sections 10μ in thickness were cut of each specimen. Despite their long immersion in spirit the histology of both specimens is surprisingly good, especially that of No. 317.

While Hill's account generally is scarcely to be improved upon, for the sake of completeness some repetition will be made here. Following is a table of the significant measurements of No. 316 and No. 317.

	No. 316	*% a.f.*	*No. 317*	*% a.f.*
Total length of urogenital system	24·83 mm.	....	19·86 mm.	....
Length a.f.(6) = combined length of vaginal system and urogenital sinus	15·01 mm.	....	11·99 mm.	....
Length of vaginal system(7)	4·43 mm.	29·51	3·11 mm.	26
Length of urogenital sinus(8)	10·58 mm.	70·55	8·88 mm.	74·06
Length of cloaca(9)	4·86 mm.	32·38	3·63 mm.	30·27
Length of urethra(10)	2·22 mm.	14·79	1·37 mm.	11·43
Length of uterine papilla	890μ	5·93	660μ	5·6

(4) From specimens R12267 and R13016 respectively, belonging to the National Museum, Melbourne.

(5) D.C.L. = Dorsal contour length.

(6) See Figure 3.

(7) The vaginal length is taken as extending from the cranial extremity of the lateral vaginae to the anterior limit of the urogenital sinus.

(8) The tip of the clitoris is taken as marking the posterior extremity of the urogenital sinus.

(9) The cloaca is taken as beginning from the point of junction of rectum and urogenital sinus and extending to the posterior limit of the vent.

(10) The urethra is regarded as commencing from the point of entry of the ureters into the bladder and extending to the anterior limit of the urogenital sinus.

Ovaries

These are small triangular to ovoid bodies about 1·05 mm. long by 0·93 mm. broad, situated near the mid-line, immediately dorsal to and in close contact with the uteri.

Large, apparently mature, ova are present in the ovaries of both No. 316 and No. 317, but those of the latter contain a relatively greater number of very small ova.

Fallopian Tubes

These are quite short and little complicated. In No. 317 the proximal part of the tubes runs forward a short distance within the wall of the uterus and parallel to the uterine cavity. The lining of the Fallopian tubes is a single layer of cubical cells with dense cytoplasm.

Uteri and uterine necks

The uteri are pearshoped bodies dorso-ventrally compressed. In No. 316 the epithelium is compact and columnar with a vacuolated cytoplasm and has mostly separated from the endometrium. The uterine glands are long and well developed. There appears to be a physiological difference between the left and right uteri. The uterine gland cells of the left uterus have deeply staining nuclei, contrasting strongly with those of the right uterus which are scarcely visible, and even with those of the histologically superior No. 317. The left uterus also contains considerable strongly staining debris, much of it membranous and possibly foetal.

The uterine epithelium of No. 317 is similar to that of No. 316 but more cubical and has remained attached to the endometrium. There is comparatively little debris in the uterine cavities and no differentiation between right and left uterine glands.

The *uterine necks*, distinguished from the uteri by the absence of uterine glands, contract gradually to run caudally within a common sheath of connective and muscular tissue. They open upon a single very prominent uterine papilla of conical form which projects backwards into the median vagina (figs. 3, 5) by two apertures in No. 317 but by only one in No. 316. This later case is undoubtedly due to a certain amount of destruction of the intervening tissue. Although not insisted upon, it is quite possible, despite it being called so here, that this conical projection does not represent the uterine papillae, but rather the wall of the anterior vaginal canal. Pearson (1950) defines the cul-de-sac (median vagina) as having its anterior limits at the level of the ora uterorum. Extensions anterior to the cul-de-sac correspond, then, to Hill's 'anterior vaginal canals' and it is this view which is adopted in the present case. In No. 316 the width of the lumen in the left uterine neck is about eight times that in the right. It is probable that this feature and the common os uterorum in this specimen are the result of foetal passage. (fig. 5).

Cul-de-sac

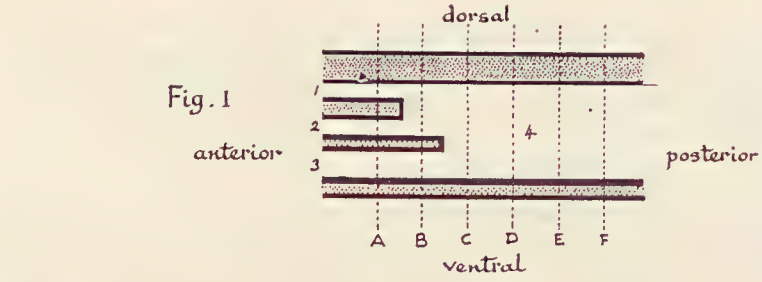
This is a dorso-ventrally compressed chamber surrounding anteriorly the uterine papilla and from the sides of which arise the lateral vaginae. Its epithelium consists of a single layer of small cubical cells which in parts are very much elongated and flattened.

There is a complete absence of a septum in both specimens, except for a vestige at the base of the uterine papilla.

The cul-de-sac passes caudally as a wide shallow chamber which, posteriorly, lies between the lateral vaginae and the urethra, communicating, in the case of No. 316, by a narrow fissure with the short posterior vaginal sinus. The latter

itself opens into the urogenital sinus a few sections later. It will be seen then that in No. 316 the cul-de-sac has become a true median vagina, thus confirming Hill's observations made fifty years earlier.

In the case of No. 317, however, the posterior end of the cul-de-sac is separated from the urethra by a solid plate of cells (fig. 8), but within this solid plate there is evidence of a future perforation that will ultimately convert the cul-de-sac into a functional median vagina having a permanent opening into the urethra.



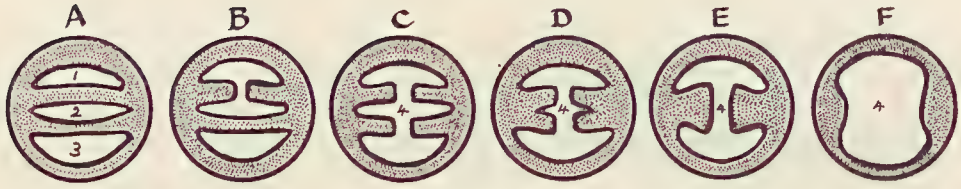


Fig. 2

FIG. 1.—Diagrammatic sagittal section showing the relations of the posterior vaginal sinus (1) and median vagina (2) with the urethra (3) and urogenital sinus (4).

FIG. 2.—Transverse sections illustrating successive levels as shown in fig. 1.

Lateral Vaginae

The lateral vaginae arise from the cul-de-sac at about the level of the ora uterorum. They curve gently caudally, converging to form a short posterior vaginal sinus before finally joining the urogenital sinus. The posterior part of each lateral vagina and a portion of the posterior vaginal sinus are occluded in both specimens, the occlusion in No. 317, however, being much greater. (figs. 4, 7, 8.)

Because they are arranged one on top of another, the true relationship between lateral vaginae, cul-de-sac and urethra is difficult to demonstrate by means of drawings. Figs. 1 and 2, show in diagramatic form the disposition of the cul-de-sac with respect to the urethra and lateral vaginae.

In the parous specimen No. 316 the lateral vaginae present a most unusual feature. (figs. 4, 5, 6 and 7.) From the posterior third of each lateral vagina a long duct passes cranially within the walls of the lateral vaginae, anterior vaginal canals and uterine necks to terminate as a small cyst or swelling.

Each duct possesses a distinct lumen for most of its length and in its course rotates around the lateral vagina in a loose spiral. It should be noted that this duct, undoubtedly the Wolffian duct, is absent in No. 317. The lateral vaginae of No. 316 have a less strongly developed muscular sheath than those of the non-parous No. 317, and present in comparison with the latter a relatively embryonic appearance.

Bladder, Urethra, Urogenital Sinus

Rotenberg, in her description of the male urogenital system of *Tarsipes* remarked on the extreme smallness of the bladder. Hill's drawing of the female system tends to confirm this. However, in the present specimens, both female, the bladder is relatively no smaller than is usual in marsupials.

The urethra is comparatively long, forming 14·79 per cent (No. 316) and 11·43 per cent (No. 317) of the combined length of vaginal system and urogenital sinus.

The urogenital sinus is slender and unusually long forming 70·55 per cent (No. 316) and 74·06 per cent (No. 317) of the above distance.

Referring to the urogenital sinus Hill says 'At its posterior end, ventrally, is the clitoris, attached throughout its length and deeply grooved dorsally, but devoid of an internal septum. A distinct cloaca is present. The cloacal opening is of characteristic form, being long, narrow and spout-like (fig. 5). A cloacal sphincter muscle is not present. A pair of large anal glands open far back into the cloaca'. This statement describes precisely the condition observed in the present specimens (fig. 9). It is probable that the deep groove on the dorsal aspect of the clitoris represents the excavated cloacal septum.

Summary of Results and Discussion

The two salient features that emerge from this study of *Tarsipes* are, first, as was noted by Hill, the existence in a parous female of a true median vagina, and secondly, the persistence of the Wolffian duct in a parous female of a highly specialized animal.

Hill referring to the presence in his doubtfully parous specimen of *Tarsipes* of a patent connexion between cul-de-sac and urogenital sinus concluded, by analogy with certain Macropods, that since this passage was open the animal had bred some time previously. He contended that '*Tarsipes* thus agrees . . . with certain species of the family Macropodinae in the possession of a direct and, after the first parturition a permanent passage for the birth of the young'. The evidence supplied by the present specimens supports this conclusion. Thus out of the two specimens described here, and the two described by Hill, three possess a true median vagina while the fourth shows signs of acquiring one.

The long duct which runs alongside each lateral vagina in No. 316, is almost certainly a vestige of the Wolffian duct. In most female marsupials the Wolffian duct degenerates long before maturity is attained, but it has been found in the course of the investigations which have been proceeding in the Tasmanian Museum for a number of years that among the Dasyuridae a vestige of the Wolffian duct persists as a very short solid rod or hollow diverticulum towards the posterior end of each lateral vagina, but never before in the course of this work has a Marsupial female urogenital system shown such a striking example of postponed regression of this embryonic structure. Its persistence in such a specialized animal is undoubtedly abnormal.

The occlusion of the posterior part of the lateral vaginae is a feature now known to be widespread among the different Marsupial families. It is mentioned here only briefly for research in the Tasmanian Museum has indicated that it is a broad question significant enough to require that a separate paper be devoted to it.

I should like gratefully to acknowledge the advice and encouragement given me in the preparation of this paper by the Director of the Tasmanian Museum, Dr. Joseph Pearson.

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Explanation of Figures

a.f.—Combined length of the vaginal system and the urogenital sinus.
bl.—Bladder.
b.s.—Blood sinus.
cl.—Clitoris.
conn.—Connexion between the median vagina and urogenital sinus.
d.—Debris within uterine neck.
d.gr.—Dorsal groove in the clitoris.
ect.t.—Erectile tissue.
l.v.—Lateral vagina.
l.l.v.—Left lateral vagina.
l.ur.—Left ureter.
m.v.c.—Median vaginal cul-de-sac.
l.ur.—Left ureter.
m.v.c.—Median vaginal cul-de-sac.
oc.l.v.—Occluded lateral vagina.
oc.p.v.s.—Occluded posterior vaginal sinus.
os.ut.—Common os uterorum.
r.l.v.—Right lateral vagina.
r.ur.—Right ureter.
s.—Septum.
s.conn.—Solid connexion of posterior vaginal sinus and urethra.
s.l.—Suspensory ligament of the clitoris.
t.cy.—Terminal cyst of the Wolffian duct.
ur.—Ureter.
ureth.—Urethra.
u.g.s.—Urogenital sinus.
ut.—Uterus.
ut.n.—Uterine neck.
ut.p.—Uterine papilla.
W.d.—Wolffian duct.

Fig. 3 Fig. 4

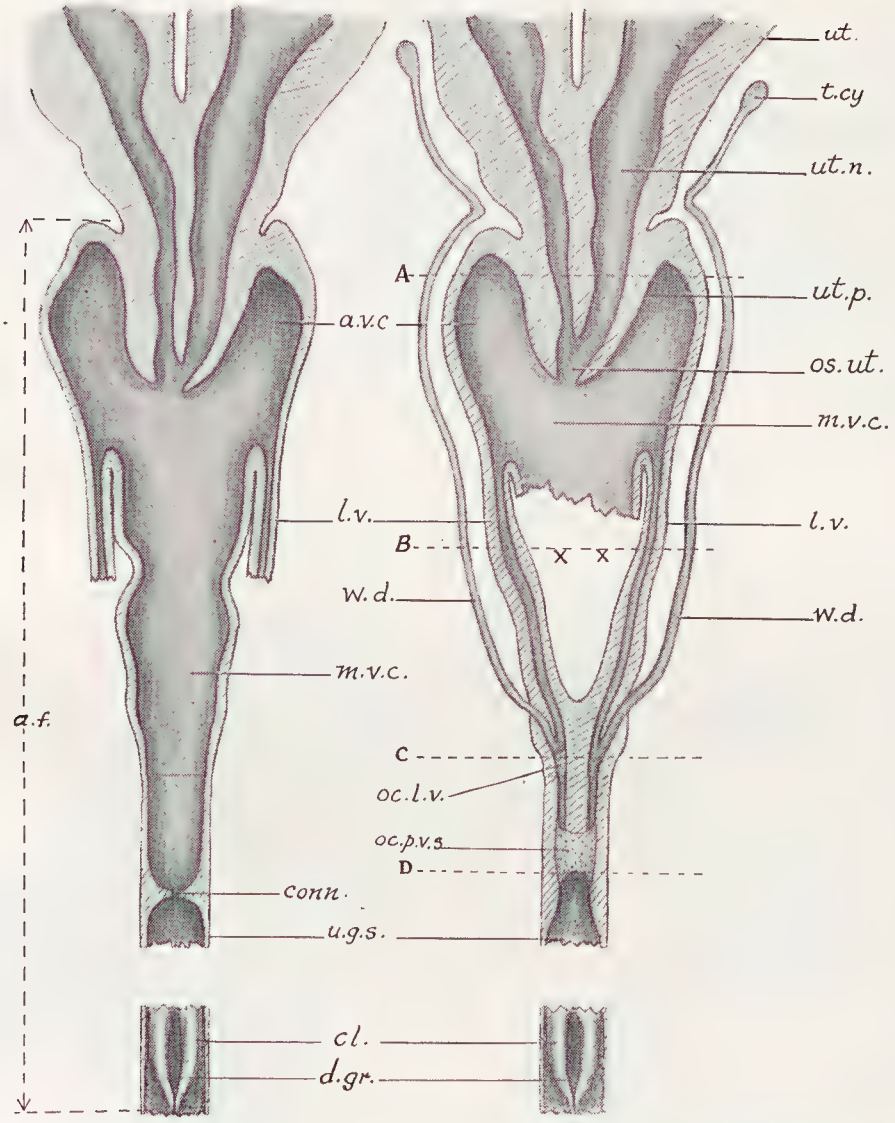
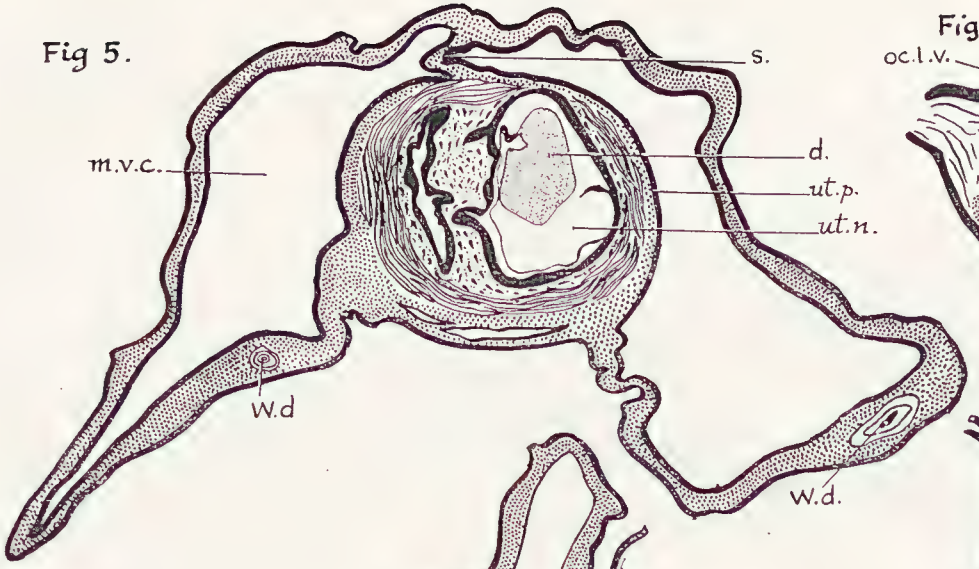
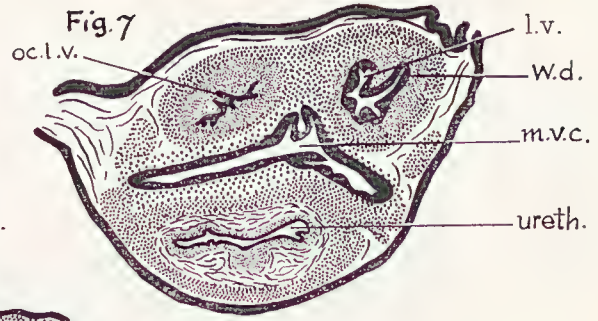
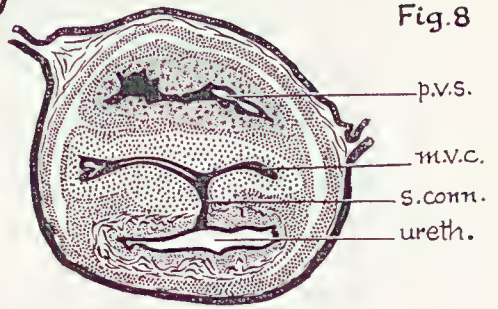


FIG. 3.—Dorsal view of the vaginal system in No. 316 showing the long cul-de-sac (m.v.c.) opening into the urogenital sinus (u.g.s.). A single prominent uterine papilla (ut.p.) projects backwards into the cul-de-sac and upon which in this specimen the uterine necks (ut.n.) open by a common os uterorum (os.ut.). The lateral vaginae have been cut away to expose the cul-de-sac lying immediately ventral to them. × 19.

FIG. 4.—Dorsal view of the vaginal system in No. 316 showing the lateral vaginae (l.v.). In this figure the posterior part of the cul-de-sac (m.v.c.) has been cut away. The Wolffian ducts, (w.d.) which actually run within the walls of the lateral vaginae, anterior vaginal canal and uterine neck, are for clarity shown separated from these structures. The two crosses mark the connexion of the ureters with the neck of the bladder. × 19.







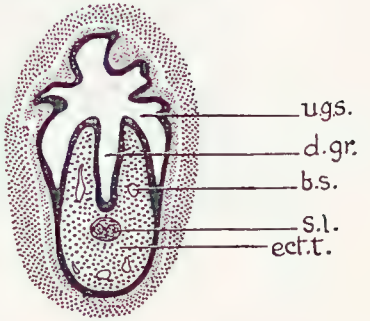


Fig.9

For reference to figures see opposite page

Explanation of Plate II

Fig. 5.—No. 316. Transverse section through A in fig. 4 showing the distended right uterine neck (ut.n.) containing a certain amount of debris (d.). At this level the Wolffian duct (W.d.) runs within the floor of the anterior vaginal canal (a.v.c.). × 60.

Fig. 6.—No. 316. Transverse section through B in fig. 4 showing the intimate association of the lateral vagina (l.v.) with the Wolffian ducts (W.d.). The left ureter (l.ur.) is just opening into the bladder (bl.).

Fig. 7.—No. 316. Transverse section through C in fig. 4 showing fusion of the right Wolffian duct (W.d.) with the right lateral vagina (r.l.v.) and the occlusion of the left lateral vagina (occ.l.v.). × 60

Fig. 8.—No. 317. Transverse section corresponding to a section through D in fig. 4 (No. 316). Right and left lateral vaginae have fused to form a posterior vaginal sinus (p.v.s.) and this is largely occluded. The cul-de-sac (m.v.c.) is also partially occluded and is joined to the urethra (ureth.) by a sheet of cells (s.conn.). × 60.

Fig. 9.—No. 316. Transverse section through the clitoris showing the deep dorsal groove. × 60.

The Royal Society of Tasmania

1950

Patron:
His Majesty the King.

President:
His Excellency Admiral Sir Hugh Binney, K.C.B., K.C.M.G., D.S.O.

Vice-Presidents:
A. L. Meston, M.A., 1950.
S. W. Carey, D.Sc., 1950, 1951.

Council:
W. L. Crowther, D.S.O., M.B., F.R.A.C.P., 1950, 1951, 1952.
M. S. R. Sharland, 1950, 1951, 1952.
W. H. Hudspeth, B.A., 1950, 1951.
F. C. Wolfhagen, LL.B., 1950, 1951.
J. W. C. Wyett, B.Sc., A.A.C.I., 1950.
D. Martin, M.Sc., 1950.

Hon. Secretary and Librarian:
Joseph Pearson, D.Sc. (Manchester), D.Sc. (Liverpool), F.R.S.E., F.L.S.

Assistant Hon. Secretary:
D. Martin, M.Sc.

Hon. Treasurer:
S. Angel.

Hon. Auditor:
A. M. Hewer.

Hon. Editors of the Papers and Proceedings:
Joseph Pearson and D. Martin.

Standing Committee:
W. L. Crowther, S. W. Carey, W. H. Hudspeth, J. Pearson, D. Martin.

Annual Report, 1950

The Annual Meeting was held in the Society's Room, Tasmanian Museum and Art Gallery, on the 7th March, 1950.

In the absence of His Excellency the Governor, President of the Society, Mr. A. L. Meston (Vice-President) presided.

The following Office-Bearers were elected:—

Vice-President: Under the Society's Rules Dr. W. L. Crowther retired from the office of Vice-President, and Professor S. W. Carey was appointed in his place (retiring 1952).

Hon. Secretary and Librarian: Dr. Joseph Pearson.

Hon. Assistant Secretary: Mr. D. Martin.

Hon. Treasurer: Mr. S. Angel.

Hon. Auditor: Mr. A. M. Hewer.

Council: Under Rule 21 Professor S. W. Carey and Mr. L. W. Miller retired as members of the Council and Dr. W. L. Crowther and Mr. M. S. Sharland were elected in their place for a period of three years.

The names of the full Council for 1950 are given on the previous page.

The Council made the following appointments at its first meeting:—

Assistant Librarian: Miss B. Veale.

Standing Committee: Dr. W. L. Crowther, Professor S. W. Carey, Mr. W. H. Hudspeth and the Hon. Secretary.

The Council elected the following two members of the Society to serve on the Board of Trustees of the Tasmanian Museum and Botanical Gardens: Mr. W. H. Hudspeth and Mr. F. H. Foster.

Meetings

Nine ordinary meetings were held during the year. At the conclusion of the September meeting a Conversazione was held in the Museum where coffee was served to approximately 250 guests. At this meeting the R. M. Johnston Memorial Medal was presented to Professor J. T. Wilson, Professor of Geophysics in the University of Toronto, who delivered the R. M. Johnston Memorial Lecture entitled 'The Development of Continents and Oceans'. In addition to the lectures given at the ordinary meetings scientific papers were submitted for publication and have been printed in the present volume.

Library

During the year 265 volumes were added to the Library in addition to a number of reports and pamphlets from British and Foreign Institutions and learned Societies. The number of Institutions on the Exchange List for the year was 260 and new exchanges were arranged with the following Institutions: Pakistan Association for the Advancement of Science: Rhodes University College, Grahamstown, South Africa; Victoria University College, Wellington, New Zealand; Société des Sciences Naturelles du Maroc. Rabat; Fisheries Research Board of Canada, Nanaimo, B.C.

The Library now consists of 24,393 volumes.

Insurance of Society Library

In 1935 the books in the Society's Library were insured for £5,000 against fire. During the year the Council decided to increase this insurance to £7,500 and to take out an additional insurance for £2,000 against malicious damage, burglary, house breaking and larceny.

Changes of staff, &c.

1. Miss Megan Griffiths, B.A., who had been seconded to the Society's Library by the authorities of the University of Tasmania, was appointed to the State Agricultural Department as Editor of the Department's publications and Librarian of the Departmental Library. The Council desires to record appreciation of Miss Griffiths' help and advice in the important work of cataloguing the Society's Library and its thanks to the University for having placed her services at the Council's disposal. Miss Griffiths took up her new duties in December 1950 and her place has been taken by Miss Barabra Veale, Assistant Librarian to the Society. Miss Veale has been transferred to the Staff of the University Library and she will continue the work of cataloguing the Society's Library. Her place as Assistant Librarian will be filled early in 1951.

2. During the year Mr. H. Exley resigned his Office of Honorary Auditor to the Society which he has held since 1944. The Council desire to record their appreciation of his valuable services. His place has been filled by Mr. A. M. Hewer.

Membership

The Society consists of the following members:—

Honorary members		2
Corresponding members		2
Ordinary members—		
Class A	235	
Class B	145	
		380
Life members		27
Associate members		11
		422

During the year 41 names were removed from the list of Members owing to deaths, resignations, &c., and 51 new Ordinary Members were elected. (Also one Ordinary Member became a Life Member and 8 Associate Members became Ordinary Members).

Deaths

The Council regrets having to record the deaths of the following members during the year:—Corresponding Member, Sir W. Benham (1901); Ordinary Members:Dr. G. H. Hogg (1918), Mr. G. A. Jackson (1919), Hon. Tasman Shields (1921), Mr. N. P. Booth (1924), Mrs. C. H. Perkins (1939), Mr. L. Cerutty (1939).

Sir William Benham, D.Sc., F.R.S., Emeritus Professor of Biology, University of Otago, New Zealand, was elected a corresponding Member in 1901 in recognition of his researches on Worms, in which group he was a world-wide authority. Sir William was also very much interested in problems of geographical distribution and wrote many papers dealing with the fauna of New Zealand.

Dr. G. H. Hogg, elected in 1918, contributed a valuable paper to the Society's Journal dealing with 'D'Entrecasteaux; An Account of His Life, His Expedition and His Officers'.

Mr. N. P. Booth was a member of the Council of the Royal Society and a Trustee of the Tasmanian Museum.

Mr. L. Cerutty was a member of the Royal Society Council and a Vice-President on one occasion. He was also interested in public affairs.

Tasmanian Museum and Botanical Gardens

During the year it was decided by Parliament to set up two new Boards, one to administer the affairs of the Tasmanian Museum and Art Gallery and the other to administer the affairs of the Botanical Gardens. These two new Boards will take the place of the old Board which has administered the affairs of the Tasmanian Museum and Botanical Gardens jointly since 1885 when the Royal Society relinquished its control over the two Institutions.

The change was effected by three distinct acts, The Tasmanian Museum and Botanical Gardens Act, No. 54 of 1950, The Tasmanian Museum Act, No. 55 of 1950, and the Botanical Gardens Act, No. 56, of 1950.

Members will be interested to know that the Society is to be represented on both of the new Boards. The composition of the two new Boards is as follows:— Tasmanian Museum Board of Trustees: (*a*) Four persons to be appointed by the Governor to hold office during his pleasure; (*b*) One person appointed annually by the Council of the City of Hobart in such manner as that Council may determine; (*c*) Two persons elected annually by the Council of the Royal Society of Tasmania as it may determine to hold office until his successor is elected.

Composition of the Botanical Gardens Board of Trustees: (*a*) Four persons to be appointed by the Governor to hold office during his pleasure; (*b*) a member of the Faculty of Science in the University of Tasmania, elected annually by the Council of the University to hold office until his successor is elected; (*c*) One person appointed annually by the Council of the City of Hobart in such manner as the Council may determine; (*d*) One person elected annually by the Council of the Royal Society of Tasmania as it may determine to hold office until his successor is elected. The Society's representatives on the Tasmanian Museum Board of Trustees are Mr. W. H. Hudspeth and Mr. Francis H. Foster, and the Society's representatives on the Board of Trustees of the Botanical Gardens is Mr. S. Angel.

National Park and Florentine Valley Bill, 1949

As the Council of the Society was concerned regarding the proposal to alienate certain portions of the National Park for the purpose of providing a forest area for the Australian Newsprint Mills Pty. Ltd., Mr. J. W. C. Wyett and Mr. E. Little were appointed to voice the Society's views before a Joint Committee of the two Houses of Parliament, which had been set up in connexion with the Bill. These two gentlemen reported that they attended meetings of the Joint Committee and submitted the views of the Council. However, in spite of the efforts of the Society and of other bodies the Bill has now become law.

Papers and Proceedings

The 1949 volume of the Papers and Proceedings was published during the year. This was an unusually large volume of 286 pages and contained 8 plates and 282 text figures. The total cost of printing and making blocks was £558, or £158 in excess of the Government Grant. This deficit was reduced to £108 by a gift of £50 by the Zoology Department of the University to cover part cost of printing three large papers writen by members of that Department. The Government has generously agreed to make a Supplementary Grant of £108 to cover the deficit. The Council wishes to record its appreciation of this generous action.

Gifts to the Society

The following is a list of gifts to the Society during the year, in addition to the numerous exchanges received from British and Foreign Institutions.

Photostate copy of old map of Hobart, c. 1859: Mr. E. R. Pretyman.

Newspaper cuttings and historical papers belonging to the late Mr. Nevin Hurst: Miss E. Hurst.

Letter from George Meredith, 2nd April, 1821: Mrs. Archer Taylor.

Documents *re* conveyance of Betsy Island: Mr. F. C. Wolfhagen.

Letters patent *re* Bishopric of Calcutta: Mr. F. Cumbrae-Stewart.

Photographs and manuscript of Aboriginal Rock Carvings, Mt. Cameron West: Mr. & Mrs. L. E. Luckman.

Letters patent *re* appointment of Sir Francis Smith as Chief Justice, V.D.L.: Mrs. H. Jeffcott, England.

Photographic negative of print of a portrait of David Gibson: Mr. K. von Stieglitz.

Purchases by Trustees of Tasmanian Museum

The following purchases, which may be of special interest to members of the Society, were made by the Trustees of the Tasmanian Museum:

A collection of stone implements, from Mrs. H. Falkinder.

Photographs of drawings of Adventure Bay, by Tobin.

The following gifts were made to the Trustees of the Tasmanian Museum during the year:

4 pictures by Hugh Ramsay: by Lady Ramsay.

3 pictures from the Allport Bequest.

Silver spade presented to Lady Hamilton on the occasion of the turning of the first sod of the Bellerive-Sorell Railway, 22nd April, 1890: by Mr. F. G. Hamilton, England.

The Royal Society of Tasmania.

Statement of Receipts and Payments for Year ended 31st December, 1950.

Receipts.	£ s. d.	£ s. d.
Balance from last account		60 6 5
Subscriptions—		
£1 10s. — 220	330 0 0	
£1 1s. — 136	142 16 0	
10s. — 10	5 0 0	
£1 — 1	1 0 0	
		478 16 0
Rentals		36 4 3
Sale of publications		5 13 0
Half cost of Conversazione—Refund from Friends of the Tas. Museum and Art Gallery		12 14 9
Transferred from Life Membership Fund Account from C.R.T.S. for shelves		40 10 0
Transferred from Funds for books		58 6 6
		£692 10 11

Payments.	£ s. d.
Salaries	202 5 9
Library	73 19 5
Northern Branch—Share subs., 1949	49 18 0
Light and power	87 15 4
Stationery, Printing and advertising	28 5 7
Miscellaneous	31 18 10
Insurance	50 11 0
Materials	16 11 10
Postage 1949 Papers and Proceedings	21 9 4
Shelves, C.R.T.S.	40 10 0
Petty Cash (cash in hand 30/12/50, £1 8s. 3½d.)	50 10 0
	653 15 1
Balance to next account	38 15 10
	£692 10 11

S. Angel, Hon. Treasurer.
A. Hewer, Hon. Auditor.

Joseph Pearson, Hon. Secretary.
A. L. Meston, Vice-President.

Royal Society Funds.

Statement of Balances for Year ended 31st December, 1950.

	£ s. d.
Reserve Account	158 9 8
Life Membership Fees	234 6 1
Clive Lord Memorial Fund (£200)	20 4 10
R. M. Johnston Memorial Fund (£232)	0 14 1
Morton Allport Memorial Fund (£200)	4 11 4
A. H. Clarke Bequest (£100)	0 7 9
Milligan Bequest (£150)	0 5 0
A. N. Lewis Memorial Fund (£250)	11 16 0

Abstracts of Proccedings

7TH MARCH, 1950

Annual Meeting

The Annual Meeting was held in the Society's Room, Tasmanian Museum. In the absence of His Excellency the Governor, President of the Society, Mr. A. L. Meston, Vice-President, presided.

The following Office-bearers were elected for 1950:—Professor S. W. Carey was elected Vice-President for two years in the place of Dr. W. L. Crowther, who retired under Rule 12, Honorary Secretary, Dr. J. Pearson; Assistant Honorary Secretary, Mr. D. Martin; Honorary Treasurer, Mr. S. Angel; Honorary Auditor, Mr. A. M. Hewer.

The following were elected members of the Council for 1950:—Dr. W. L. Crowther and Mr. M. S. R. Sharland were elected for three years in the place of Professor S. W. Carey and Mr. L. W. Miller, who retired under Rule 21.

The following was elected a member of the Society:—Miss M. L. Ibbott.

Mr. K. von Stieglitz delivered an illustrated lecture entitled 'Early Settlement in the Northern Parts of Norfolk Plains'.

4TH APRIL, 1950

A meeting was held in the Society's Room. Professor S. W. Carey, Vice-President, presided.

The following were elected members of the Society:—Mrs. G. Needham, Mrs. F. M. Ruthven, Mr. J. D. Brown, Mr. J. Connor, Mr. G. M. Dimmock, Professor T. Hytten, Mr. N. M. Hudson, Rev. H. M. Maddock, Mr. Malcolm Miller, Mr. H. J. King, Mr. G. S. Norman, Mr. S. Thyne.

Mr. J. Bradley delivered an illustrated lecture entitled 'The Growth of Mountains'.

2ND MAY, 1950

A meeting was held in the Society's Room. Mr. A. L. Meston, Vice-President, presided.

The following were elected members of the Society:—Mr. J. R. Erp, Mr. A. N. Mann, Mr. I. H. Walker.

Mr. John McLean delivered an illustrated lecture entitled 'Adventure Bay and the Early Explorers' of which the following is an abstract:—

> The lecturer stressed the desirability of having historic sites marked at Adventure Bay, Bruny Island, because there was a danger of some sites being lost.
>
> No other place on the coasts of Australia has such an interesting 'pre-settlement' history, as the ships of three English and two French expeditions anchored here between the years 1773 and 1802; yet on the fifteen miles of the Bay's coastline there is not a cairn or signpost to denote the sites of the following events: Captain Cook's first and only meeting with the Tasmanian aborigines; the place where Cook made the first presentation of medals in Australia; the site where Captain Cook stepped off Australian soil for the last time before his death; the *Bounty's* watering place and swapit; the place where Captain Bligh planted the first apple and other fruit trees in Tasmania; Bligh's meeting place with the aborigines.
>
> It is not generally known that Adventure Bay was Midshipman Matthew Flinders' first landing place in Australia, and was the only harbour in Australian waters visited by the *Bounty*
>
> The rediscoveries of the historical sites required research and exploration of slight topographical changes and was accomplished by the lecturer when he became a resident of the district. The various situations mentioned by the illustrious navigators are in almost the same condition as when their ships sailed out of the bay. He strongly urged that eight or nine of these historic sites should be marked by cairns or signs.

6TH JUNE, 1950

A meeting was held in the Society's Room. Professor S. W. Carey, Vice-President, presided.

The following were elected members of the Society:—Dr. J. B. Polya, Mr. E. G. Butler, Mr. R. A. Ferrall.

Mr. H. L. Greener delivered a lecture entitled 'Educating the Whole Man'.

4TH JULY, 1950

A meeting was held in the Society's Room. Mr. A. L. Meston, Vice-President, presided.

The following were elected members of the Society:—Mr. M. L. Conway, Mr. R. L. Phillips, Mr. H. A. Hudson, Mrs. D. Lyle.

Mr. M. S. R. Sharland delivered an illustrated lecture entitled 'Australian Sea Birds'.

1ST AUGUST, 1950

A meeting was held in the Society's Room. Mr. W. H. Hudspeth presided.

The following were elected members of the Society:—Mr. D. E. Kurth, Miss I. Thomson, Mr. S. H. Butler, Dr. H. M. Fisher, Dr. L. A. Langley, Dr. A. M. McArthur, Mr. E. S. Padman.

The Chairman explained that this meeting arose out of discussions which had taken place with the Miniature Camera Club in connexion with a scheme which has been considered both by the Council of the Royal Society and the Trustees of the Museum to build up a collection of photographs of historic buildings in the Hobart district. Two members of the Miniature Camera Club, Mr. G. Cramp and Mr. R. Hope-Johnstone, showed slides of old buildings and of photographs taken during a trip to Lake Pedder.

8TH SEPTEMBER, 1950

A meeting was held in the Society's Room. His Excellency the Governor, President of the Society, presided.

The following were elected members of the Society:—Miss M. T. Noall, Mr. H. B. Boss-Walker, Mr. J. N. Elliston, Mr. G. E. Hale.

His Excellency presented the R. M. Johnston Memorial Medal to Professor J. T. Wilson, Professor of Geophysics in the University of Toronto, Canada, who then delivered a lecture entitled 'The Development of Continents and Oceans'. (see p. 85.)

3RD OCTOBER, 1950

A meeting was held in the Society's Room. Professor S. W. Carey, Vice-President, presided.

The following were elected members of the Society:—Miss H. F. Gulline, Mr. R. H. Hardman, Mrs. W. E. Cameron, Miss L. M. Goninon, Miss M. M. Godfrey, Mrs. K. E. Graves, Mr. A. T. Abbott, Mr. H. W. Askeland, Mr. W. E. Cameron, Mr. R. J. Foot, Mr. A. E. Garrott, Mr. A. M. Graves, Mr. E. Hart, Mr. P. J. Payton, Mr. S. V. Sydes, Mr. G. L. Wymond.

Professor H. N. Barber delivered a lecture entitled 'Scientific Freedom in the Soviet Union'.

14TH NOVEMBER, 1950

A meeting was held in the Society's Room. Mr. A. L. Meston, Vice-President, presided.

The following was elected a member of the Society:—Mr. J. A. Cardno.

The following papers which had been submitted for publication in the Society's Journal were tabled and it was agreed to submit them to the Standing Committee:—

(1) New Phorocidiinae and the affinities of the New Zealand spider *Atkinsonia nana* Cambridge, by V. V. Hickman.
(2) The Identity of Spiders belonging to the Genus *Amaurodioides Cambridge*, by V. V. Hickman.
(3) Notes on the intertidal ecology of the Freycinet Peninsula, E. R. Guiler.
(4) The intertidal ecology of Pipe Clay Lagoon, by E. R. Guiler.
(5) The Distribution of the pea crab, *Fabia hickmani*, by E. R. Guiler.
(6) A list of the marine algae of Tasmania, by E. R. Guiler.
(7) The distribution of certain intertidal animals, by E. R. Guiler.
(8) The female urogenital system of the dasyurid sub-families Phascogalinae, Dasyurinae and Thylacininae, by Joseph Pearson and J. M. de Bavay.
(9) Observations on the Surface Structure of the Hairs of Tasmanian Monotremes and Marsupials, by A. G. Lyne and T. S. McMahon.

Professor T. Hyten delivered a lecture entitled 'The Dollar Problem', of which the following is an abstract:—

The Dollar Problem was caused by maladjustments resulting from two world wars and the uneasy peace between these wars. The national self-sufficiency aimed at by most nations after the first world war was costly in that it reduced efficiency and decreased the volume of world trade, ultimately causing the depression of the 'thirties. After the last war there was a shortage of manpower, materials and capital equipment, in addition to the destruction of our whole pre-war system of production and a comparatively free enterprise, which was now being hampered by the difficulty of abandoning controls and restrictions.

America had shown her willingness to help first, by the Lend-lease system during the war, and Marshall Aid after the war, but America had apprehensions in regard to countries that went much further than she herself was prepared to in regard to social legislation, and also because the American, on the whole, works longer hours, and rather more effectively, than workers in the countries for which she was providing aid. There was also the fact that there were in America few fugitive funds from the countries she was aiding, notably France.

It could be contended that there was no actual dollar shortage in the world providing these funds could be mobilized and used for dollar imports to the countries earning them.

The remedies were to use Marshall Aid for developing productive enterprise rather than for consumption, and to develop the export trade of the Sterling Area as well as to substitute imports as far as practicable from the rest of the Sterling Area for imports from the dollar area.

Northern Branch.

Annual Report for 1950

5TH APRIL, 1950

The Annual General Meeting of the Royal Society of Tasmania, Northern Branch, was held at the Museum on the 5th April, 1950.

The Annual Report and Balance Sheet were adopted.

Mr. J. E. Heritage presided.

Under the rules the following Office-bearers were elected:—

Chairman: Dr. C. Craig.
Vice-Chairman: Mr. J. E. Heritage.
Council: Rev. J. C. Jones, Mr. G. C. McKinlay, Dr. W. K. McIntyre, Mr. C. G. Ryan.
Acting Secretary: Miss I. Thomson.

A lecture was given by Mr. D. Martin, Officer-in-Charge, C.S.I.R.O., Hobart, on 'Tasmanian Eucalypts in the British Isles'.

Mr. Martin said that the introduction of Tasmanian eucalypts into the British Isles had begun when the early voyagers took back plants with them. These early introductions were sporadic and it was not until Baron von Mueller became Government Botanist of Victoria that the eucalypt was to be found in many places overseas. In Britain a number of collections of eucalypt species were planted on estates and although trees were still living on many of these, the plantations were now largely neglected.

MEETINGS

During the year four Council meetings and five General meetings were held.

27TH JUNE, 1950

A meeting was held at the Museum, Mr. J. E. Heritage presiding.

Mr. C. L. Speedy, M.Sc., cosmic ray physicist to the Macquarie Island Expedition, 1948, gave a lecture on 'Life on Macquarie Island'.

He told of the purpose of the Expedition—to establish a weather station that would be useful on long range weather predictions, and spoke of the personnel. He illustrated his talk with studies of the fauna and marine life of the Island.

22ND AUGUST, 1950

A meeting was held at the Museum, Mr. J. E. Heritage presiding.

Mr. K. R. von Stieglitz spoke on 'Early Pioneers of Norfolk Plains'.

This area extended from Henrietta Plains (Powranna) to Devonport and Port Sorell and was defined in 1811. The area attracted the London capital of two Companies:—The Cressy establishment and the V.D.L. Company. The V.D.L. Co. however, later moved to the N.W. Coast being granted land there. Interesting incidents of these times were related by the Speaker.

26TH SEPTEMBER, 1950

A meeting was held at the Museum, presided over by Dr. C. Craig.

Mr. W. Gellie gave a talk on 'Early Days in Launceston'.

He gave a resumé of the visit of Collins and of Paterson's settlement at York Town. He related incidents in the early life of Launceston dealing with early inns, mail services, water supplies, shipping and buildings.

7TH NOVEMBER, 1950

A meeting was held at the Museum. Dr. C. Craig presided.

The speaker was Mr. W. Sutherland, M.A., who spoke on 'Linguistic Changes in name in Tasmania with special reference to those of Scottish origin'.

He dealt with changes in pronunciation and in forms of words. He pointed out that Scottish surnames have not survived as English principally because—

(1) there are more English, (2) Scotch becomes modified abroad, and (3) Scottish influence on language abroad has never been strong although sometime it has been asserted as when Governor Macquarie named so many places after those in Scotland.

Mr. Sutherland said that Scots were slaves to spelling and believed that words themselves had value; they always wanted to pronounce all letters. England's tradition was a spoken, not a written one. The speaker illustrated his points with many examples.

HISTORICAL EXPEDITIONS

Historical Expeditions were held to York Town, Cypress Street, Cemetery, Longford, and George Town.

Royal Society of Tasmania.

Northern Branch.

Statement of Accounts at February 28, 1951.

Receipts.	£	s.	d.
Balance at March 1, 1950	54	0	11
Subscriptions	71	4	8
Bank interest	0	9	0
	£125	14	7

Expenditure.	£	s.	d.
Petty cash	34	3	2
Balance forward	91	11	5
	£125	14	7

L. G. Shea, Government Printer, Hobart, Tasmania.

NATIONAL MUSEUM
OF VIC

S1533